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ANOMALIES OF REFRACTION

AND OF THE

Muscles of the Eye

BY

FLAVEL B. TIFFANY, M.D.

PROFESSOR OF OPHTHALMOLOGY AND OTOLOGY OF THE UNIVERSITY MEDICAL COLLEGE OF KANSAS CITY, MO.; OCULIST AND AURIST TO ALL SAINTS' AND GERMAN HOSPITALS; OCULIST TO THE M., K. & T. R. R.

MEMBER OF THE INTERNATIONAL MEDICAL CONGRESS, PAN-AMERICAN ASSOCIATION AMERICAN MEDICAL ASSOCIATION, AMERICAN MICROSCOPICAL SOCIETY, MISSOURI STATE MEDICAL ASSOCIATION, KANSAS STATE MEDICAL ASSOCIATION, MISSOURI VALLEY MEDICAL SOCIETY, ETC.

Vox a occasu solis.

AUTHOR'S SECOND EDITION.

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PREFACE.

In no branch of medicine or surgery within the last decade has there been more attention given or more discoveries or advancements made than in the department of ophthalmology; particularly, the anomalies and affections of the ocular muscles and of refraction; and yet, these vast subjects of heterophoria and ametropia are still wrapped in a halo of uncertainties. That some anomaly of the ocular muscles, of refraction, or of both, is accountable for many of the pains, aches, and ills of the body and for many of the different forms of chorea and hysteria, is being more and more recognized by the profession in general.

In no branch of medicine have there been invented so many instruments and apparati for the disclosure of disease as for those anomalies and affections which are incident to this little organ of vision; and in no branch of the science, it would seem, is it so necessary that a settled and definite plan be adhered to in the ferreting out of these occult affections and complications as in ophthalmology. The general practitioner is often unable to cure cases of these anomalies, and sends them to the oculist, and the oculist is frequently put to his wits end and ofttimes completely "stumped" in trying to disclose the real pathological or functional disorder or defect.

It is said that the inmates of insane asylums, homes for the feeble-minded, and prisons are, with few exceptions, either ametropic or heterophoric. It would seem, then, that these anomalies may bear some intimate relation to man's moral nature. The manner and degree in which a ray of

light is bent from its course as it passes through the different dioptric media, together with the beautiful and complete mechanism of accommodation which enables the eye to receive these impressions, whether they come from near or afar, has much to do with man's correct estimate of the material world about him.

That the faculty of vision shapes largely the destiny of man, warps or fashions his fate or his moral nature, there is little doubt.

The subject of "eye-sight" of school children is now attracting the attention not only of the medical profession, but of thinking people throughout the land, and especially of educators. Our venerated teacher, Prof. Donders, taught us that the ideal eye, the normal eye, as to its refraction, is so constructed and adjusted as to bring parallel rays of light to a focus upon its retina without any effort of accommodation; in other words, it is the *emmetropic eye.*

In some recent publications it has been asserted that the hyperopic eye is the normal condition, and that this normal eye is always keyed up to a certain amount of muscular tension, whether it is adjusted for near or for distant objects, and one writer says that the whole subject of refraction and accommodation, in his opinion, should be rewritten. Be this as it may, the subject under consideration is still in a mist, and I may be pardoned if I, in my humble way, contribute my mite in the endeavor to shed more light on the subject, from my personal experience and observation, both in my public clinic and private practice.

In writing this little volume, it has been my purpose to present the subject in as clear, brief, and concise a manner as possible, embracing all essentials, besides collaborating recent advancements not to be found in the existing books. I have also been stimulated to write the book from repeated requests made by my students to whom I have presented this subject didactically and clinically for the past thirteen years. To one of these students in particular am I indebted for the valuable assistance he has rendered by his knowledge of stenography, by the making of many of the drawings, assist-

ing in the proof-reading, etc. It is to my friend and former student, H. D. Jerowitz, M.D., I say, that I am indebted for valuable assistance.

To another, who by her keen, bright intellect and accurate, honest mind has rendered me much assistance in this as in other of my literary efforts, am I indebted, and to whom I dedicate this book—my wife, Olive E. F. Tiffany.

FLAVEL B. TIFFANY, M.D.

Kansas City, April, 1894.

PREFACE TO THE SECOND EDITION.

When the first edition of this work was placed upon the market (now about a year and a half ago), it was with some anxiety upon the part of the author as to how it would be received by the profession, and what place it might take among the many kindred works already out. It is certainly gratifying to know that the book has been so pleasantly received. It is evidently filling a need, as the first edition is already exhausted. The second edition has been carefully revised, and contains some additional data and illustrations, together with some of the more recent developments.

F. B. T.

2457 Troost Avenue, Kansas City, Mo., 1896.

Plate I.

H. v. Helmholtz

PROFESSOR VON HELMHOLTZ.

Hermann Louis Ferdinand von Helmholtz, of Berlin, was born in Potsdam, August 31, 1821; studied in the University of Berlin in 1838, as pupil in medicine and surgery; was graduated from the Frederick Wilhelms Institute in 1842, with the inaugural thesis, entitled "De Fabrica Systematis Nervosi Evertebratorum"; under-surgeon in the Charité; 1843, army physician in Potsdam; returned in 1848 as teacher of anatomy at the Academy of Arts and assistant at the Anatomical Museum at Berlin. Was called in 1849 to the professorship of physiology and universal pathology at Königsberg, and in 1855 was transferred as professor of anatomy and physiology at Bonn; from thence he went as professor of physiology to Heidelberg in 1858; in 1871 at Berlin he accepted, together with the direction of the Physical Institute, a professorship of physics, with the character of Privy Government-Counsellor, and in 1883 was ennobled, which title he now bears.

He belongs to the class of the Johannes Müller's school. He became famous as a physiologist and established his calling with the work "Ueber die Erhaltung der Kraft" (Berlin, 1847), in which he for the first time seeks to show that all the transactions of nature obey the fundamental laws of mechanics. In the following year Helmholtz's activity was turned to the physiology of the mind. But the invaluable service he gave to human pathology and therapeutics through the invention of the ophthalmoscope, which entirely revolutionized ophthalmology, he made known in another work, "Beschreibung eines Augen-Spiegels zur Untersuchung der Netzhaut im lebenden Auge" (Berlin, 1851).

Among other works claiming our highest admiration, and in their special spheres pointing out new phases of science, are: "Handbuch der physiologischen Optik" (Leip-

zig, 1856–66), in which his whole investigations upon the eyesight are laid down, and his book (now being revised by Dr. Arthur König, of Berlin), "Die Lehre von den Tonempfindungen" (Braunschweig, 1862; 2d edition, 1865), which contains his acoustic investigations, displayed in collation. Besides, he has a large class of other works; for instance, Measurements of the Rapidity of Transmission of Nerve Irritation; investigations upon articles on optics, acoustics, electricity teachings; manifold articles in journals; others in Müller's *Archiv.* (1845–48–50–52, etc.), Poggendorff's *Annalen* (of 1852 *et seq.*), and Crelle's *Journal of Mathematics;* from Graefe's *Archiv.* (1855); also, such small works as "Ueber die Wechselwirkung der Naturkräfte," etc. (Königsberg, 1854), "Ueber das Sehen des Menschen" (Leipzig, 1855), "Populäre Vorträge" (2d part, Braunschweig, 1865–7) are published. His scientific treatises are together in two volumes (Leipzig, 1881–83); his reports and discourses are also in two volumes (Braunschweig, 1884).

The subject of this sketch, on the 8th of Sept., 1894, died at his home (Charlottenberg, near Berlin), in his 73d year. Dr. Knapp, who was a personal friend of Prof. Helmholtz, says in his obituary (*Archives of Ophthalmology*, October, 1894): "The allotment of his time for waking and sleeping, work and recreation, home-life and travel, was such as to make his labor in the highest degree efficient, and his life not only the most useful, but also most enjoyable and healthy. He hated to be annoyed by idlers and and scientific pretenders. In the lecture-room he was always precise and unswervingly adherent to the subject, never being 'out of order,' despising jokes and stories to amuse his audience. He kept the attention of his listeners by the wealth of interesting facts and the clearness, precision, and elegance of his delivery. He was constantly in contact with his pupils, aiding and assisting them. . . . Taking him all in all, he was as near a perfect man as Nature has ever produced, the gift of the highest intellect combined with nobility of character and purity of life."

Plate II.

BIOGRAPHICAL SKETCH OF PROF. DONDERS.

The following brief biographical sketch of Prof. F. C. Donders is a translation in part (by Olive E. F. T.) of a very beautiful tribute furnished by one of his disciples, our friend Le Docteur E. Landolt:

"Since the death of Von Graefe ophthalmology has not met with a loss comparable to that which it has just experienced in the person of Donders. It might be said that we do not lose the master, since his works remain and will always remain, forming the life, the soul of ophthalmology.

"When, last year, his country, his pupils, his compatriots, his admirers from far and from near, united by one common sentiment of gratitude, changed into an apotheosis the retreat from the professorship which the limitation of age imposed upon him, Donders towered above the crowd who were deifying him, by his noble presence, the loftiness of his brow, the nobility and brilliancy of his look.

"On this day, glorious among all days for him, in which every one rendered homage to his merits, he responded modestly: 'Talk not to me of my merits, but congratulate me on my lucky star.'

"Donders was born May 27th, 1818, in Tilbury, Holland, of poor parents, the ninth child, the first son. It is said that the joy of having at last an heir killed his father. Of what supreme joy did fate deprive the father by taking him off at the cradle of his only son! The mother watched over that cradle with a double solicitude, but although the heart of this great man always kept the impress of the cares of this tender mother, it is neither the society of his town nor the school of Duizel, where he learned Latin and earned his living as sub-master until he was thirteen years of age, which can claim the honor of having deposited in him the germs of his future greatness. He continued his studies of Latin in the school of Boxmeer until he was seventeen years of age. He became, consequently, very strong in this use-

ful language. He threw himself with great ardor into the medical sciences in the military school of Utrecht. In 1840, at twenty-two years of age, he occupied the chair of military surgeon at La Haye. The year 1842 saw him already the distinguished professor of anatomy and physiology in the same school of Utrecht which he had but just left as pupil.

"Who would have said then that he would live sixty-seven years in this little city of Utrecht; that he would grow up in it and shine in it to such a degree as to make of this fireside of his activity a scientific center, beneficently radiating its light over the whole world, even after his death? What a brilliant epoch, moreover, was that in which Donders began to cultivate the fertile field of the sciences of man!

"Schwann had just demonstrated the cell origin of all organisms; Von Baer had just discovered the egg of mammalians; Bischoff, the segmentation of the ovule; Henle had endowed science with his marvelous book of anatomy, notably of microscopic anatomy; and the immortal Jean Müller had opened new horizons to physiology by introducing into it the exact sciences. So emulation was not wanting in the new school, or rather in the school newly developing, which was illustrious with the names of Helmholtz, Brüche, Claude Bernard, and Ludwig. Donders was the worthy representative of Holland in this noble phalanx.

"There is not a domain in this vast science in which Donders has not left priceless traces of his labors. The life of tissues, circulation of the blood, digestion, secretions, movements, organs of senses, language, secrets of the nervous system, were, turn by turn, explored by this indefatigable seeker. He explained the formation of vowels, measured the rapidity of our thoughts, demonstrated the laws of evolution, of animal life, and the indestructibility of force.

"If there is a crowd of facts, of laws, of theories, which make illustrious his name, there are perhaps as many which we consider as belonging to science from all eternity, without knowing that we owe them to Donders. If the acquisition of knowledge has more charm than the possession, Donders found a joy still greater in its communication to

others. His first researches were published in the *Nederlandsch Lancet*, which he founded with Jansen and Ellermann; also in the *Holländische Beiträge*, which he published in German with Van Dee and Moleschott, 1846.

"What Donders preferred most of all was teaching *viva voce*, and what did he teach? Let us ask rather, what did he not teach? He possessed all the qualities which make the perfect professor: an erudition as profound as extensive; an excellent memory; an intelligence capable of adapting itself to his audience; a wit which colors abstract matters; a rich flow of language; a voice sonorous and flexible; gesture noble and significant; something sublime emanated from the man; physically grand and beautiful, something at once imposing, captivating, and sympathetic; great knowledge, and great desire to impart it."

As an instance of his great modesty we cite the reply made to one who attributed to him the discovery of astigmatism: "Pardon me, my friend, astigmatism was known a long time before my day; I only discovered astigmatic people." When a hospital and laboratory were needed in Utrecht, the name of Donders was already so well known, this prophet was so esteemed in his intelligent country, that he had only to lift his voice, to see gifts flowing in from all quarters sufficient for the creation of the two institutions in which Holland has eternally honored herself.

The following is the first account rendered by himself: "I have seen the unfortunate who had believed his existence terminated by blindness thank God on seeing open before him a new period of happiness. I have seen the honest workman, once humiliated in eating the bread of charity, capable of earning again for himself and for his the savory bread of labor. I have heard the cries of joy of the young mother, who, long deprived of the sight of her child, could not turn away her eye with its new glimmering light from her baby's face; and I have seen, in the child snatched from blindness and beginning to learn, how much nature is reflected the more willingly, and consequently the more divinely, in the eye of the child."

There is no student of ophthalmology but is acquainted

with this sage and erudite teacher through his great work on Refraction, the source from which much knowledge is drawn by every writer on this subject.

It was our good fortune to meet Prof. Donders in his home at Utrecht in the fall of 1887, and we shall never forget the warm welcome he gave us, strangers as we were. It was enough for this grand, noble soul to know that we had crossed the seas to meet and shake hands with our great teacher. It was indeed a proud and happy moment for us to sit and have communion with the great master—a bright spot in our lives that will never be forgotten.

F. B. T.

Plate III.

Dr Landolt

EDMUND LANDOLT, M.D.

It was at Washington, D. C., during the meeting of the Ninth International Medical Congress of 1887, we first had the pleasure of meeting Dr. Landolt, who contributed much to the success of our section by his scientific communications and his discussions.

A few months later found us at No. 27, Rue Saint-André des Arts, Paris, where a few weeks were spent with pleasure and profit listening to his enthusiastic and able teachings, especially concerning the subjects of Refraction, of Insufficiency of the Ocular Muscles, and of Strabismus. Dr. Landolt may be called a specialist within the specialty of ophthalmology. He has contributed largely to this subject.

His masterly work on "Refraction and Accommodation of the Eye" is regarded as authority by the student of to-day, as was and is the work of Donders on the same subject by all students.

He was born in the town of Aarau, Switzerland, in the year 1846. To his early life passed in this picturesque country, in this beautiful scenic land of hills, lakes, and mountains, with clear, running streams, may be attributed, in a measure, his cheerful disposition and keen powers of observation.

He studied in Heidelberg and Zurich. Received the degree of M.D. in 1869 at Zurich, and in 1875 at Paris. He was assistant surgeon to the surgical clinic in Zurich; later, surgeon to the ophthalmological clinics of the same university (Prof. Horner). Passed one year with Arlt in Vienna and Von Graefe in Berlin, another with Donders and Snellen in Utrecht. Visited the principal clinics in Germany, England, Italy, France; later, those of the United States of America. During the Franco-German War (1870–71) was surgeon-in-chief to the ambulance in Héricourt (France). Settled in Paris 1875. Organized, with Javal, the laboratory for ophthalmology at the Sorbonne.

Among his *principal works* (OVER ONE HUNDRED) are: "On the Retina," in Max Schultze's *Arch.*, 1870. "Amblyopie hystérique," *Arch. de physiol.*, 1875. A manual of examination of the eyes, published in French and in English, 1879. A manual of ophthalmoscopy, published in French, English, Dutch, and Spanish. "Traité complète d'ophth.," with M. de Wecker, 4 volumes. "The Refraction and Accommodation of the Eye, 1886 (Edinburgh), 600 pages. "The Operation for Cataract in Our Time," *Arch. d'ophth.* and *Ophth. Record*, 1892. "The Anomalies of the Motor Apparatus of the Eyes," in "System of Diseases of the Eye," edited by Norris and Oliver (1893–4).

Among the principal instruments invented by Dr. Landolt are: Landolt's perimeter, ophthalmoscope, ophthalmodynamometer, forceps for strabotomy, double-bladed knife for discission.

Dr. Landolt is consulting surgeon to the Institution of the Young Blind in Paris.

CHAPTER I.

REFLECTION OF LIGHT.

As reflection and refraction of light have to do with the anomalies of refraction and accommodation of the eye, we shall briefly consider these phases of optics before entering upon the subject of ametropia.

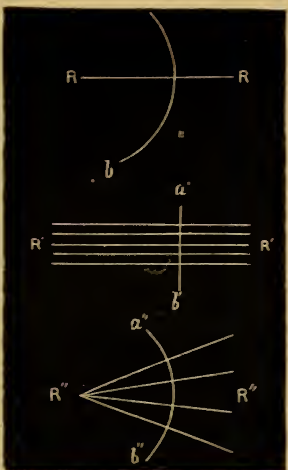


Fig. 1.

Light, by its action on the retina of the eye, excites the sensation of vision. The source of light may be natural or artificial. The line in which light is propagated is called a *luminous ray* (RR, Fig. 1). A collection of parallel rays is called a *beam* of light (R'R'). A collection of divergent rays from a point is a *pencil* of rays (R''R'').

In Figure 2 are represented a few of the infinite number of pencils of light emitted by three luminous points of a candle flame. Every point of an illuminated object (*ab*) receives light from every luminous point of the candle flame. Thus it follows that

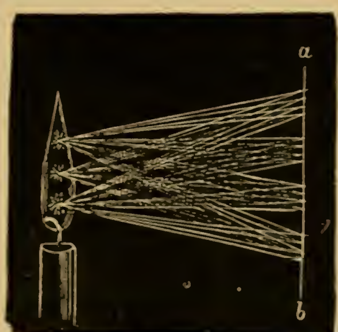


Fig. 2.

every point in a luminous body is an independent source of light, and emits light in every direction.

In a homogeneous medium, light is propagated in a straight line, but it changes its direction when it passes into a medium of different density.

Images Produced by Small Apertures. If light from objects illumined by the sun—as trees or houses—passes through a small aperture and strikes a white screen, rays carrying with them the color of the points from which they issue will imprint their own color on the screen, and inverted images of the objects in their true colors will appear upon it. This may be shown by holding in a darkened room a candle flame in front of a cardboard, having a pinhole in its center; the image will be projected on the wall. (Fig. 3.)

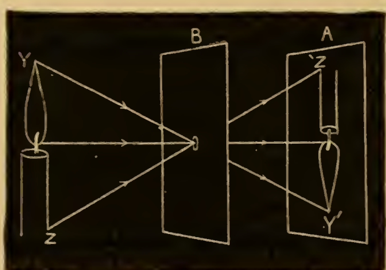


Fig. 3.

The shape of the image is always the same as that of the object and is independent of the shape of the aperture. The inversion of the image arises from the fact that the luminous rays cross one another in passing through the aperture, the lower part of the object becoming the upper part of the projected image.

When a luminous ray meets a polished surface it is reflected according to two laws:

1. The angle of reflection is equal to the angle of incidence.

2. The incident and the reflected ray are both in the same plane, which is perpendicular to the reflecting surface.

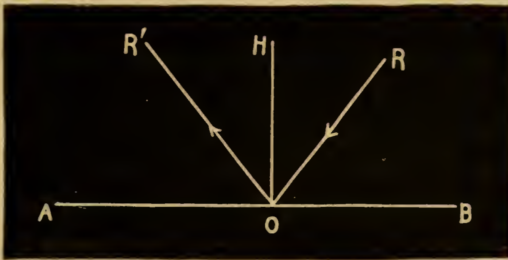


Fig. 4.

In Figure 4 let RO be an incident ray striking the polished surface AB at the point O, and OH the perpendicular erected at that point. The ray RO is reflected in the direction OR′, making the angle HOR′ equal to the angle ROH.

MIRRORS. A body with a polished surface that will show by reflection objects presented to it is known as a *mirror*.

Mirrors may be either plane or curved; that is, they have either a plane or a curved surface.

REFLECTION FROM PLANE MIRRORS. MM (Fig. 5) represents a plane mirror. AB and HE are pencils of rays coming from the points A and H of the object AH. The reflected pencils BC and EC are divergent. The reflected rays entering the eye in the direction BC and EC are seen as if they came from ND. The position of ND can be determined by tracing backwards the lines of the pencils BC and EC until they meet. In the case of a plane mirror the image is as far behind the mirror

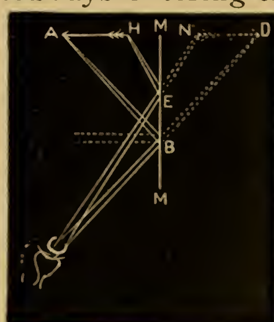


Fig. 5.

as the object is in front of it, and is of the same

size and shape as the object. But the image is reversed, as can be demonstrated by standing before a mirror. The image of the right hand is on the left of the image in the glass. If the mirror is horizontal, with its reflecting surface upwards, and the object above it, the image will be inverted, as can be shown by placing a glass of water upon a looking-glass (Fig. 6).

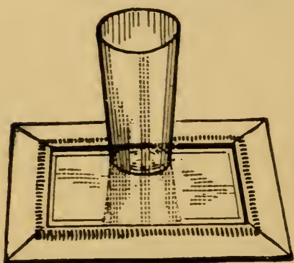


Fig. 6.

The image formed by a plane mirror is called a *virtual* image, as there can be no real image at the place where it appears, there being no reflected rays behind the mirror.

When the reflected rays themselves meet, they form a *real* image. The prolongations of the reflected rays form a *virtual* image.

Fig. 7.

The surfaces of waters, when at rest, act as mir-

rors. Probably they suggested the mirror—'twas the mirror of Venus and Narcissus. A body of water, for instance, when calm, will produce images of external objects, as of the moon, stars, buildings, etc. Figure 7 represents the phenomenon of such a reflection. In this case, it is the same as for the image formed by a horizontal looking-glass.

Curved Mirrors. This class comprises those in which the reflecting surface is a portion of a hollow sphere. If the concave side is used for reflection, it is a *concave* mirror; if the outer or convex side is employed, it is a *convex* mirror.

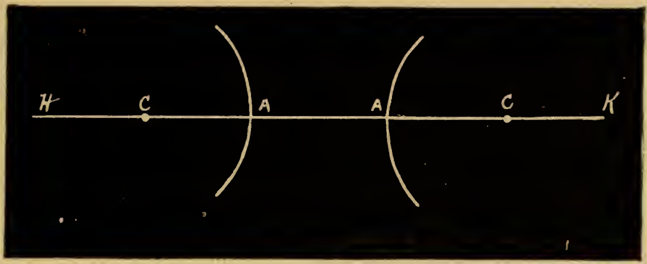


Fig. 8.

In both concave and convex mirrors the middle point (A, Fig. 8) is the *vertex* of the mirror. The center of the sphere of which the mirror forms a part is called the *center of curvature* (C). A straight line (HK) drawn through the center of curvature and vertex of the mirror is called th *principal axis* of the mirror.

Reflection from Concave Mirrors. A concave mirror may be considered as made up of an infinite number of

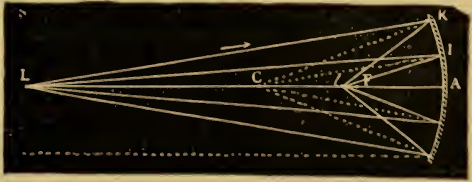


Fig. 9.

small plane surfaces. All radii of the mirror, as CK, CI, and CA (Fig. 9), are perpendicular to the small planes which they strike.

If C were a luminous point, all rays emanating from it, and striking the mirror, would be reflected back to C.

Let L represent any luminous point. The rays LK and LI emanating from this point strike the mirror at the points K and I and are reflected to meet at a point *l*. The angle of incidence LKC is equal to the angle of reflection CK*l*, CK, the radius, being the perpendicular. Any other ray from L striking the mirror will be reflected to *l*. The rays before reflection are divergent, but after reflection are convergent and meet. The place of meeting (*l*) is called the *focus*, and is the focus of all rays coming from the point L. It is obvious that rays emerging from the point *l* would come to a focus at L, since the angle of incidence and the angle of reflection would interchange, but still be equal. Two points in such relation, in which rays coming from one are focused at the other, are known as *conjugate foci*.

If the luminous point L were nearer to C, the focus would also be nearer to C, as the angle of incidence would be smaller, and consequently the angle of reflection would also be smaller.

If the point L is further removed from C, the angle of incidence becomes greater, which makes the angle of reflection correspondingly greater, and the point *l* approaches the mirror. If L is removed to an infinite distance, the rays would be almost parallel; hence, rays may be regarded as practically

parallel when their source is at a great distance; *e. g.*, fixed stars.

For practical purposes, we shall speak of the rays coming from a distance of 20 feet or more from the eye, as parallel, and call them *infinite rays;* while rays coming from a distance less than 20 feet from the eye may be considered divergent, and these we shall designate as *finite rays.*

Parallel rays striking a concave mirror become convergent by reflection, and meet at a point F (Fig. 10) in the principal axis. This point, which is called the *principal focus* of the mirror, is just half way between the center of curvature and the vertex of the mirror. On the other hand, *divergent* rays proceeding from the principal focus become parallel after reflection.

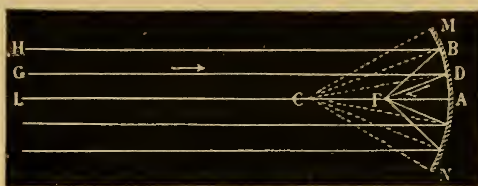


Fig. 10.

Rays emanating from a point between the principal focus and the mirror (L, Fig. 11) will become divergent after reflection, and take the directions ME and NH. These lines cannot meet, and consequently there is no real conjugate focus for L. But if the lines are prolonged backwards, they meet at a point. This point (*l*) where the prolongations of the reflected rays meet is known as a *virtual* focus, and the image resulting from these is analogous to those formed by plane mirrors.

Fig. 11.

If the rays (previously rendered convergent by

another concave mirror, or by a converging lens) strike the mirror in the direction of EM and HN in Fig. 11, they will come to a focus between the mirror and the principal focus, as at L.

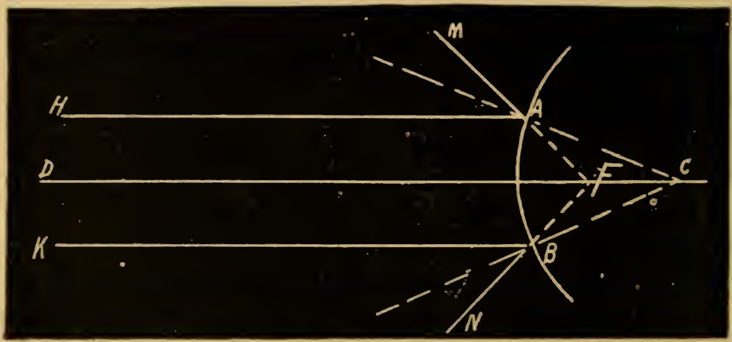


Fig. 12.

REFLECTION FROM CONVEX MIRRORS. In convex mirrors, which may also be regarded as composed of an infinite number of small plane surfaces, there are only virtual foci; for parallel rays, as HA and KB (Fig. 12), become divergent after reflection, and take the directions AM and BN, whose prolongations backward meet in the principal axis at F and form a virtual focus; which in this case—the primary rays having been parallel—is half way be-

Fig. 13.

tween the center of curvature and the mirror, and is the *principal virtual focus* of the mirror.

If the rays come from a finite distance, as, for instance, point E (Fig. 13), a virtual focus (H) will be formed between the principal focus and the mirror.

IMAGES FORMED BY CONCAVE MIRRORS.

1. If an object be held in front of a concave mirror, but at a greater distance from it than its center of curvature, an image is formed which is located between the principal focus and the center of curvature, and it is real, inverted, and smaller than the object. This is illustrated in Fig. 14.

Fig. 14.

A pencil of rays from the point D in the object DE is reflected by the mirror, and comes to a focus (D′) in the secondary axis DB (which is a line drawn from any point of an object through the center of curvature); then D′ is the conjugate focus of D and locates its image. The same explanation applies to E and all intermediate points of the object DE, and we have a real, inverted image at E′D′, which may be projected upon a screen. The pencils of rays, after coming to a focus at E′ and D′, will, if prolonged, become divergent again, and the eye placed at a distance beyond the object will receive these divergent rays and will see the image of the object. This accounts for the fact that when we look into a concave mirror or reflector from a distance, we see a small, inverted image of ourselves in front of the mirror. This can be beautifully shown by using the head-mirror or the ophthalmoscope, such as is used for examining the throat or eyes.

2. The converse of the above needs no

separate explanation. The object is placed at E′D′, and its image is therefore at DE and may also be projected upon a screen. From this we deduce our second rule: The image of an object placed between the principal focus and the center of curvature is also real and inverted, but is larger than the object, and is located beyond the center of curvature.

3. If the object be placed between the principal focus and the mirror, the image is virtual, erect, larger than the object, and is back of the mirror (Fig. 15).

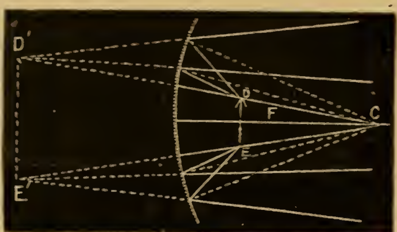


Fig. 15.

DE is the object. The rays emanating from it become divergent after reflection, and cannot come to a focus; but their prolongations backwards form virtual foci, and thus make a virtual image. The lines CDD′ and CEE′ are secondary axes. From

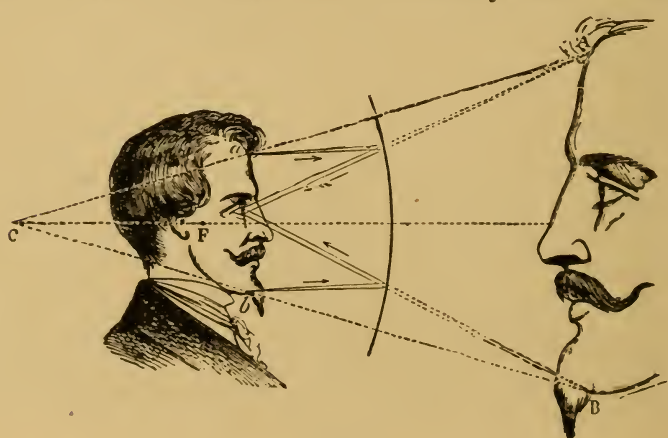


Fig. 16.

this we see how a person looking into a concave

mirror, when being near it, will see an enlarged image of himself, as in Fig. 16.

4. If the object be at the center of curvature, the rays will strike the mirror perpendicularly and be reflected back to the same point, and hence the image will coincide with the object, or, in reality, there is no image at all.

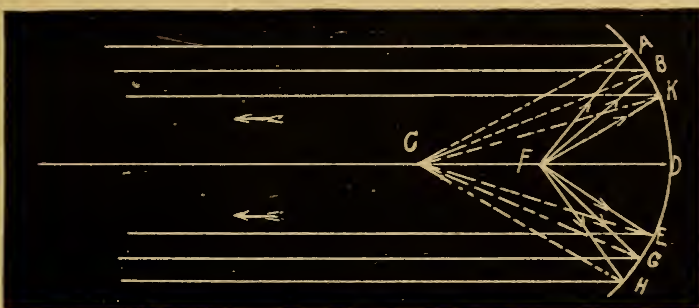


Fig. 17.

5. If the object be at the principal focus, there can be no image, as the reflected rays are parallel; and there can be no focus, as shown in Fig. 17. This can also be demonstrated by the head-mirror or the ophthalmoscope.

IMAGES PRODUCED BY CONVEX MIRRORS. If we look into a convex mirror, we shall see a small, upright image of ourselves, which becomes larger as we approach the mirror, and smaller as we recede from it. If an object comes in contact with the mirror, the image is as large as the object. If only a part of the object touches the mirror, the part that touches it will be of the original size,

Fig. 18.

while the other parts of the image will be smaller, so that the entire image is deformed.

Any image produced by a convex mirror is virtual. Fig. 18 shows how the image is produced.

The rays after reflection are divergent and their prolongations meet in the secondary axes, producing the virtual image.

CHAPTER II.

REFRACTION OF LIGHT.

A knowledge of the subject of refraction of light is of paramount importance in the adjustment of spectacles for the different anomalies of the eye. Without a knowledge of the laws governing refraction, serious errors may arise in the attempt to correct these anomalies. Thus the use of improper glasses, whether chosen by the patient himself or selected by the jeweler, optician, or vender of spectacles, without scientific application of the laws of refraction, is liable to produce serious injuries. Frequently, the oculist finds hypermetropes wearing concave glasses which were selected by some person possessing no scientific knowledge of optics, these glasses intensifying the anomaly instead of giving relief to the eye. The blame in such cases is usually attributed to the spectacles, and the patient naturally condemns spectacles in general.

When a beam of light passes from one medium to another of different density, as from air into water, it is bent or refracted at the boundary plane between the media, unless it falls exactly perpendicular to this plane. If it passes into a denser medium, it is refracted towards the perpendicular erected at the point of incidence; if into a rarer medium, it is refracted away from it.

Let AC (Fig. 19) represent the surface of a body of water, and *m*E an incident ray striking it at an angle. It is refracted in the direction of E*n*,

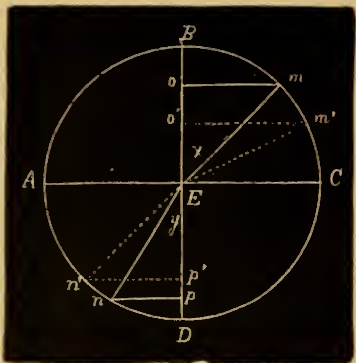


Fig. 19.

toward the perpendicular ED. If *n*E be considered a ray passing out of the water into the air—a rarer medium—it is refracted *from* the perpendicular EB and takes the direction E*m*. The angle *m*EB is the *angle of incidence*, angle DE*n* is the *angle of refraction*, and angle *n*E*n'* is the *angle of deviation*.

In the circle with E as a center the perpendiculars *om* and *pn* are dropped to the perpendicular BD; *om* is the sine of the angle *m*EB, and *pn* is the sine of the angle DE*n*. Now, suppose that the value of *om* is $\frac{8}{10}$—*i. e.*, it is $\frac{8}{10}$ of the radius E*m*—and the value of *pn* is $\frac{6}{10}$; then we have the sines of the two angles, one to the other as $\frac{8}{10}$: $\frac{6}{10}$ or as 4:3. The quotient $\frac{4}{3}$, obtained by dividing the sine of the angle of incidence by the sine of the angle of refraction, is called the *index of refraction*, $\frac{4}{3}$ being the index of refraction of light in passing from air into water. In passing from air into glass the index is $\frac{3}{2}$, and if the order is reversed, the reciprocal of these fractions must be taken as the indices; that is, from water into air it is $\frac{3}{4}$ and from glass into air it is $\frac{2}{3}$. The refractive index varies also with the color of the light.

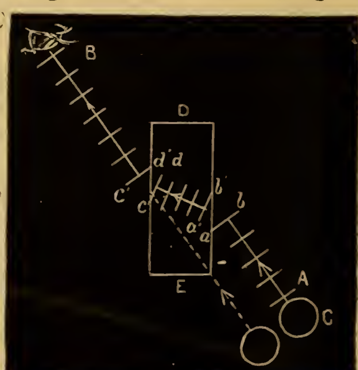


Fig. 20.

Cause of Refraction. It has been observed that the velocity of light is less in a dense than in a rare medium. Let the series of parallel lines A and B (Fig. 20) represent a series of wave-fronts leaving an object C, and passing through a rectangular piece of glass DE. Every point in a wave-front moves with equal velocity as long as it traverses the same medium; but the point *a* of a given wave *ab* enters the glass first, and its velocity is impeded, while the point *b* retains its original velocity; so that while the point *a* moves to *a′*, *b* moves to *b′*, and the result is that the wave-front assumes a new direction within the glass. Again, the extremity *c* of a given wave-front *cd* first emerges from the glass, when its velocity is immediately quickened; so that while *d* advances to *d′*, *c* advances to *c′*, and the direction of the ray is again changed, and it is parallel to its direction before entering the glass. The eye placed at B sees the object as if it came from the other circle in the figure. If the light strike the glass perpendicularly, all points of the wave will be checked at the same instant on entering the glass, and hence will suffer no refraction.

Effects of Refraction. Place a coin or some other object in the bottom of an empty vessel (preferably not transparent) and at such a position that the coin shall just be hidden by the side of the vessel, as at B (Fig. 21). Whilst in this position let water be poured into the vessel and the coin will

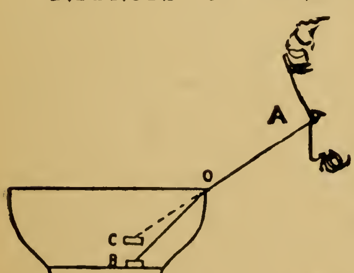


Fig. 21.

at once become visible at C. This is due to the refraction of the rays coming from the coin. The effect of refraction makes the bottom of the vessel seem higher than it is in reality.

The ray from B after emerging at O is refracted in the direction OA, which makes the coin visible in the same line—*i. e.*, at C in the straight line AOC.

Having described the principles of refraction, we shall now apply the same to prisms and lenses.

PRISMS. An optical *prism* is a transparent, wedge-shaped body. Fig. 22 represents a transverse section of such a prism. A is the apex or summit and MN is the base.

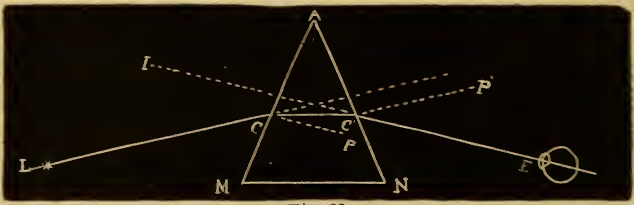


Fig. 22.

The ray LC on entering the prism is refracted towards CP, a perpendicular erected at the impinging point, and takes the direction CC′; on emerging, it is refracted from the perpendicular C′P′ and takes the direction C′E. The point L appears as if it came from I. The rays are always refracted towards the base of the prism. It is essential that this fact be thoroughly fixed in the mind, as spectacles are in reality formed of prisms.

Fig. 23 shows the manner of displacement caused by viewing an object through a prism. The object always appears deflected towards the apex of the prism.

LENSES. Any transparent medium bounded by two curved surfaces, or one plane and the other curved, is a *lens*.

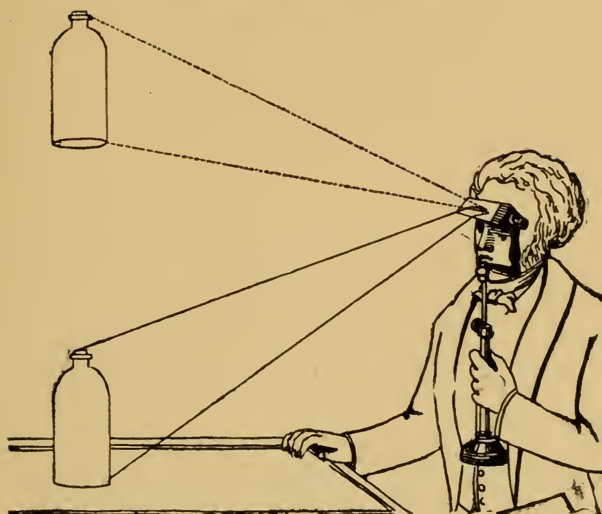
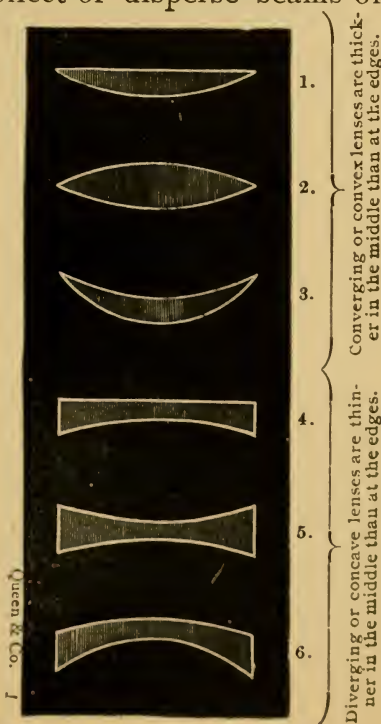


Fig. 23.

Lenses are of two classes, converging and diverging, according as they collect or disperse beams of light. Each class comprises three kinds:



CLASS 1.

1. Plano-convex.
2. Double-convex.
3. Concavo-convex.
(*Convex meniscus.*)

CLASS 2.

4. Plano-concave.
5. Double-concave.
6. Convexo-concave.
(*Concave meniscus.*)

Of these, the double-convex, double-concave, and meniscus are the ones mostly used as spectacles, and which we shall dwell on more particularly.

The lenses just described are known as *spherical* lenses, because one or both of their surfaces forms part of a sphere. When the surfaces of a lens form part of a cylinder, it is known as a *cylindrical* lens.

CYLINDERS. Cylindrical lenses are of great importance, and are much used for the correction of anomalies of refraction. Of late, they have been especially brought into requisition, and further attention will be given to them under the subject of astigmatism.

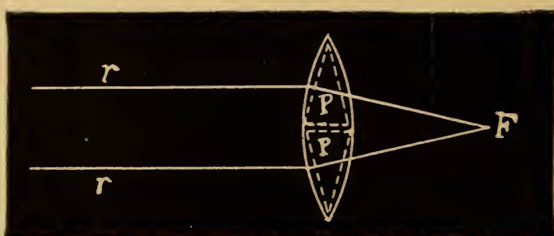


Fig. 24.

The *bi-convex* lens may be regarded as composed of two prisms placed together base to base, as in Fig. 24.

The rays *rr* are refracted towards the bases of the prisms PP, and converge to meet at the point F, which is called the *focus*. If the rays are parallel, this point is called the *principal focus* of the lens, and its distance from the lens is known as its *focal length*.

The focal length of a double-convex lens is equal to the radius of the circle of which the curvature of the lens forms a part. The focal length of a plano-convex lens is equal to the diameter of the circle.

In Fig. 25 the focal length of the double-con-

vex lens L is the radius DC, and parallel rays, as RR, will come to a focus at C. The focal length of the plano-convex lens L′ is the diameter AB, and parallel rays, as R′R′, will come to a focus at A.

The lens L is twice as strong as the lens L′.

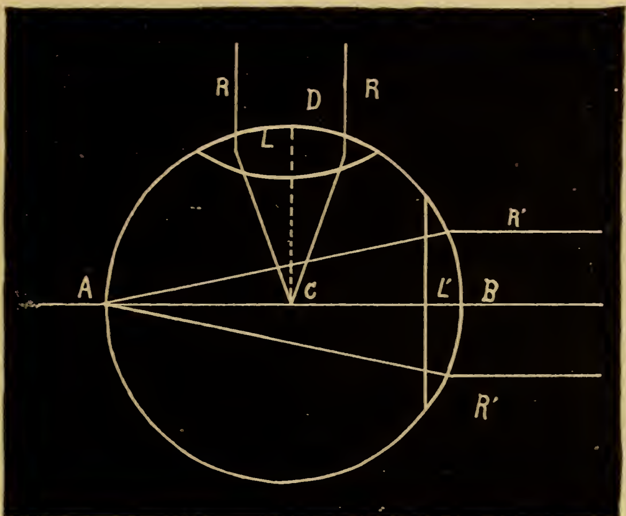


Fig. 25.

A lens with a greater convexity than L will require a smaller circle, and hence a smaller radius, and will be stronger. It follows, then, that the shorter the focal length of the lens, the stronger is its power of refraction.

A straight line, as AB (Fig. 26), perpendicular to both surfaces of any lens, and passing through its two centers of curvature, is called its *principal axis*.

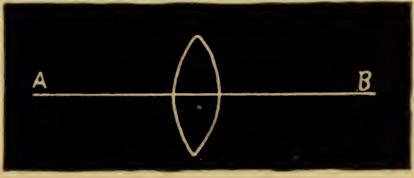


Fig. 26.

In every lens there is a point in the principal axis called the *optical center*. Any ray that passes

through this point will, after emerging, assume the same direction that it had before entering the lens. A line drawn through the optical center from any point of an object is called a *secondary axis*, as AB (Fig. 27).

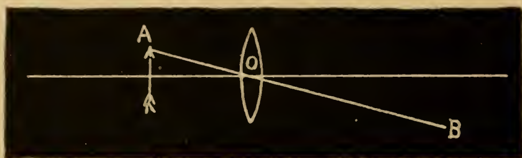


Fig. 27.

We have already stated that parallel rays striking a bi-convex lens become convergent after refraction, and meet at a point in the principal axis, called the principal focus. From this, it is obvious that divergent rays emanating from the principal focus as a luminous point may become parallel after passing through the lens, as shown in Fig. 28.

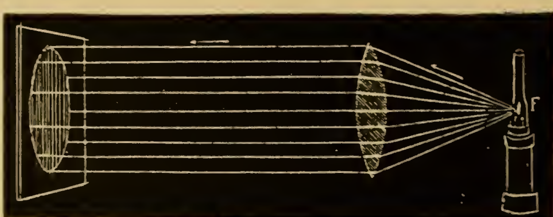


Fig. 28.

Rays coming from a point beyond the principal focus at a finite distance are divergent, but will become convergent after refraction, and come to a focus, as in Fig. 29.

Rays from S are focused at S′, and rays from S′ would be focused at S. Two points thus related—*i. e.*, where rays from one are brought to a focus at the other—are called *conjugate foci*.

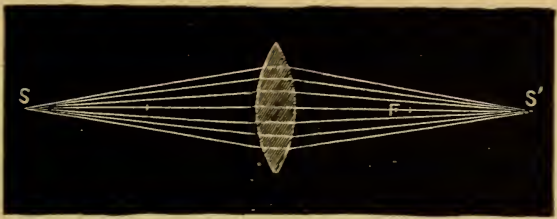


Fig. 29.

Rays emanating from a point nearer the lens than the principal focus will be divergent after refraction, but the divergence will be less than before they meet the lens, as shown in Fig. 30.

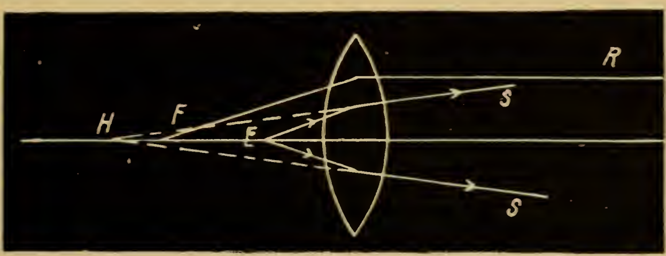


Fig. 30.

R is a parallel ray which has its origin in the principal focus (F), and becomes parallel by refraction. SS are divergent rays originating in the point E, nearer the lens than the principal focus.

Conversely, convergent rays (previously rendered so by another convex lens) striking a convex lens will come to a focus at some point between the principal focus and the lens; thus, in Fig. 30, if we consider the rays SS as coming convergent towards the lens, they will meet after refraction at the point E.

Fig. 31.

A *double-concave* lens may be regarded as composed of two prisms placed with their apices together, as represented in Fig. 31.

Parallel rays (*rr*) are refracted towards the bases of the prisms (PP), and thus become divergent. From this it will be seen that concave lenses have the property of dispersing or diverging parallel rays of light. If the rays *rr* were divergent, they would become still more divergent after refraction. If we prolong the refracted rays backwards, they will meet at some point in the principal axis. This point (F, Fig. 32) is a virtual or imaginary focus; and if the incident rays have been parallel, this point is the *principal virtual focus* of the lens.

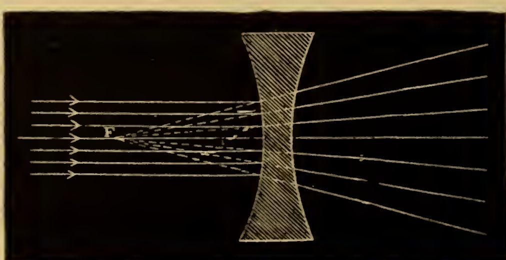


Fig. 32.

Convergent rays (previously rendered so by a convex lens), as *r′r′* (Fig. 31), may become parallel after passing through the lens. If the rays should be still more convergent, they would come to a focus at some place behind the lens.

Formation of Images by Convex Lenses. If an object be placed in front of a convex lens, each pencil of rays coming from every point of the object, and meeting the lens, is brought to a focus somewhere behind the lens (providing that the object be outside of the principal focus). The as-

semblage of these foci makes up a picture of the object which is called its *image.*

Images and their formation vary according to the distance of the object from the lens.

1. *Object at a distance greater than twice the focal length of the lens.* The image in this case is beyond the principal focus, nearer the lens than the object, real, inverted, and smaller than the object. It is, of course, on the other side of the lens.

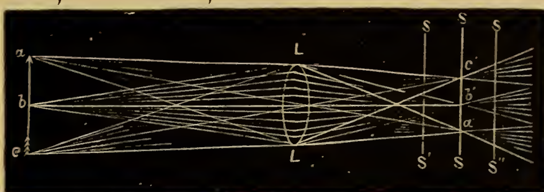


Fig. 33.

In order to explain the method of the formation of the image, we may take any two points of an object, and if we take the terminal points, their foci will determine the place and size of the image. Let us take the points *a* and *c* in the object *abc* (Fig. 33). The line *aa'*, passing from the point *a* through the optical center of the lens, is the secondary axis, and all rays emanating from *a* will come to a focus at some place in the secondary axis, as at *a'*. This point is the conjugate focus of *a*; for all rays coming from one of these two points will be focused upon the other. Similarly for *c* and all intermediate points, as *b*, for instance, which has its conjugate focus at *b'*. Thus we have a real, inverted image. If a screen be placed at SS, a perfect image will be seen; but if placed either at S'S' or S''S'', the image will be blurred.

2. *Object at a distance less than twice the focal length, but beyond the principal focus.* This is the converse of the above. The image will be on

the other side of the lens, further from the lens than twice the focal distance, larger than the object, inverted, and real. Fig. 34 illustrates this. AB is the object and *ba* its image.

Fig. 34.

3. *Object at a distance equal to twice the focal length of the lens.* In this case the image will be at a distance equal to twice the focal length behind the lens—*i. e.*, as far behind the lens as the object is in front of it. The image will be of the same size as the object, real, and inverted.

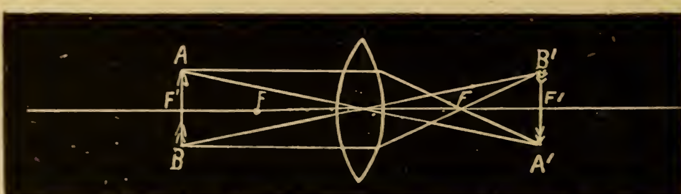


Fig. 35.

In Fig. 35 F is the focal distance of the lens, and F′ marks out twice the focal length. We see that the object and the image are both at a distance of twice the focal length from the lens.

4. *Object at the principal focus.* Rays of light proceeding from the principal focus, as we have already shown, become parallel after emerging

from the lens, and cannot meet. Thus no focus is formed, and no image can result. (Fig. 36.)

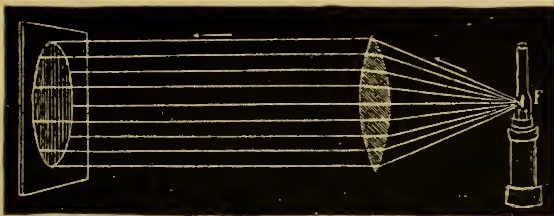


Fig. 36.

5. *Object nearer the lens than the principal focus.* We have already observed that rays coming from between the principal focus and the lens are still divergent after refraction, but less so than before meeting the lens. The refracted rays, therefore, cannot meet to form a focus; but if we prolong these refracted rays backwards, as shown in Fig. 37, their prolongations will meet, and form a virtual focus (H), which is on the same side of the lens as the origin of the rays, and further

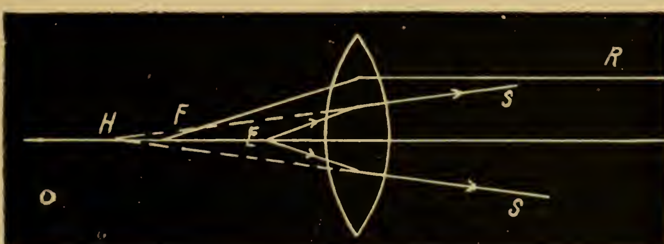


Fig. 37.

away from the lens. An object, therefore, placed between the principal focus and the lens will have its image on the same side of the lens as the object, but farther away. The image is virtual, erect, and larger than the object; or, in other words, we have a magnified, erect image of the object,

which we can see by placing the eye on the other side of the lens, as in Fig. 38.

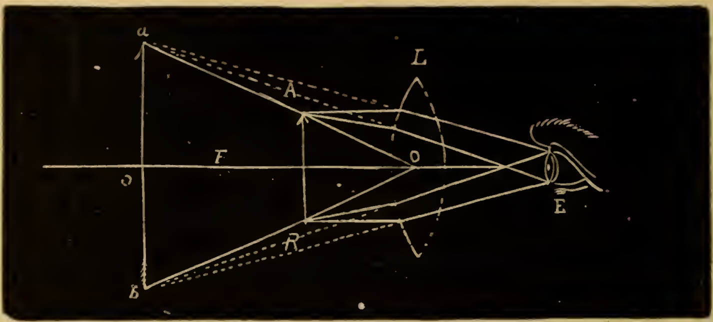


Fig. 38.

A convex lens used in this manner is called a *simple microscope.*

The focus of a convex lens is a focus of heat as well as of light. If a paper be kept at the principal focus for a short time, the lens being exposed to the sun's rays, the paper will take fire. This property of lenses has been used to procure fire, and may be used for discharging a cannon; the lens may be so arranged that the cannon is discharged at a certain time every day by the concentration of the sun's rays. (Fig. 39.)

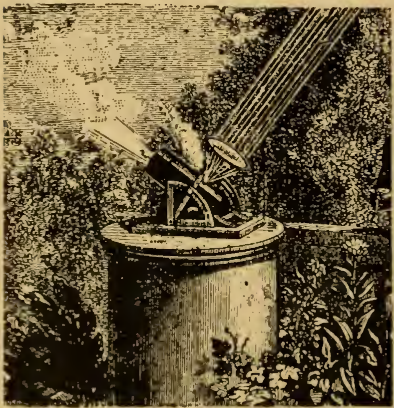


Fig. 39.

A lens used for this purpose is called a *burning-glass*.

(Strong cataract glasses are liable to injure the eyes if the person looks with them at the sun.)

COMPOUND MICROSCOPE. When it is desired

to magnify an object more than can be done with distinctness by a single lens, a compound microscope is employed. This consists of a series of lenses—convex and concave, to correct spherical and chromatic aberration—acting together as a convex lens, the *objective* M (Fig. 40); and a convex lens as *eye-piece* (N). The objective forms a magnified, real image of the object AB at *ba*. The eye-piece magnifies the image *ba* to the size of *b′a′*.

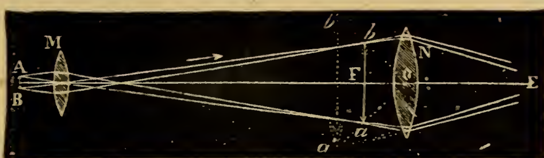


Fig. 40.

ASTRONOMICAL TELESCOPE. The astronomical telescope consists essentially, like the compound microscope, of two series of lenses; namely, an *objective* O (Fig. 41), which forms a real, diminished image *ba* of the object AB, and an *eye-piece* E, which magnifies this image to the size *dc*.

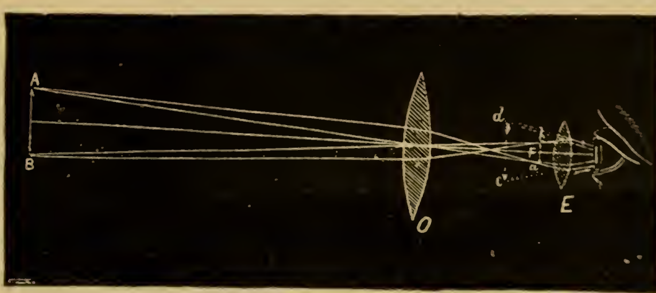


Fig. 41.

PHOTOGRAPHER'S CAMERA, OR CAMERA OBSCURA. Fig. 42 represents a vertical section of the camera. This consists of a box painted black

on the interior. A screen of ground glass S forms a partition in the box. A sliding tube T contains a convex lens L. If an object is placed some distance in front (D), and the distance of the lens from the screen is suitably adjusted by means of

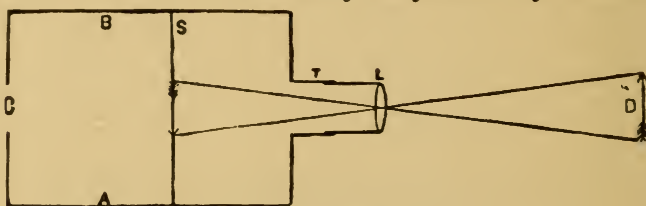


Fig. 42.

the tube T, a distinct, real, and inverted image can be seen upon the screen by looking through the aperture C. When the image is properly focused, the photographer replaces the ground-glass plate by a sensitized plate, and the chemical power of the sun's or "electric arc" rays paints a true picture of the object on this plate.

FORMATION OF IMAGES BY DOUBLE-CONCAVE LENSES. Let AB (Fig. 43) represent an object, and MN a double-concave lens. The rays from A and B after refraction become still more divergent. By prolonging backwards the refracted rays, they meet at A′ and B′, forming there a virtual image. This image (A′B′) is erect, smaller than the object, and nearer the lens than the object. This is always the case, whatever the distance of the object. The eye placed on the other side of the lens sees the

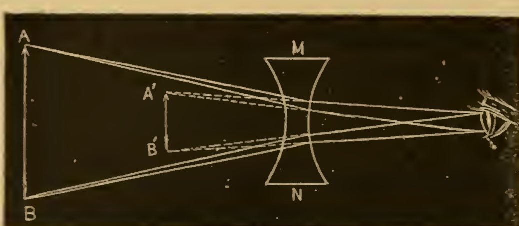


Fig. 43.

object nearer the lens than it really is, and the object appears smaller.

SPHERICAL ABERRATION. The angle AFB (Fig. 44), formed by drawing lines from the edge of the lens to the principal focus, is known as the *aperture* of the lens.

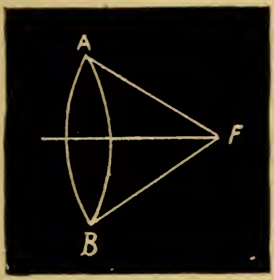


Fig. 44.

As long as this angle is less than 10 or 12 degrees all parallel rays will meet at the principal focus, but if the angle is greater, the rays which traverse the lens near the edge will be refracted to a point F (Fig. 45) nearer the lens than the principal focus (G).

Rays passing near the axis from A (Fig 46) come to a focus at F, while those passing near the edge of the lens cross the axis at F′.

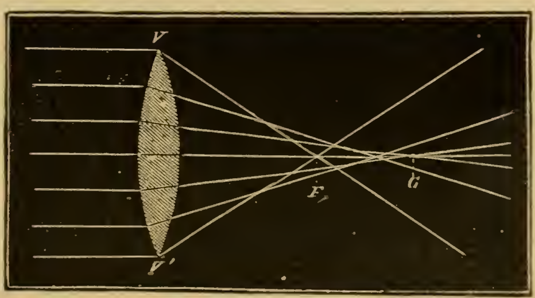


Fig. 45.

This wandering of the rays from a single focus

Fig. 46.

is called *spherical aberration.* The evil may be largely corrected by interposing a diaphram DD′,

provided with a central aperture smaller than the lens, so as to obstruct those rays that pass through the marginal part of the lens.

DECOMPOSITION OF LIGHT. If a beam of sunlight pass through a prism, it is not only bent from its course, but is also decomposed into its various colors (Fig. 47), which together form the *solar spectrum*. It is due to the unequal refrangibility of the different colored rays, the violet being refracted the most and the red the least. The spectrum is composed of seven primary colors, occurring in the following order: violet, indigo, blue, green, yellow, orange, and red.

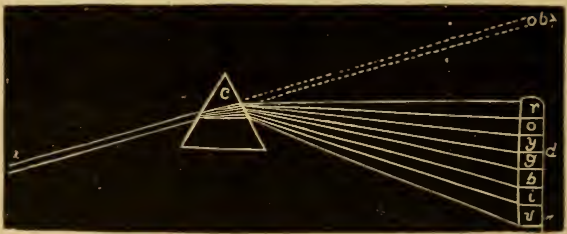


Fig. 47.

The colors of the spectrum are simple. If one color of the spectrum be allowed to pass through a hole in a screen and then fall on a second prism, it is refracted, but there is no change of color.

RECOMPOSITION OF LIGHT. The colors of the spectrum may be reunited so as to produce white light.

Fig. 48.

1. If it be acted on by a second prism exactly like the first with its refracting edge turned in the opposite direction, the light will be recomposed and will emerge as white light. (Fig. 48.)

The emergent pencil E is parallel to the pencil S. This amounts to the same as passing light through a medium bounded by parallel surfaces.

2. If the spectrum be received upon a concave mirror, it will be recomposed and a colorless image produced. (Fig. 49.)

Fig. 49.

The color of a body is due to the fact that it absorbs certain colors and reflects or transmits others; thus, if a body absorbs all the colors except red, it appears red. Those that reflect or transmit all colors in the proportion in which they exist in the spectrum are *white*, while those which transmit none are *black*.

CHROMATIC ABERRATION. Light passing through a convex lens is decomposed as well as refracted. The tendency, therefore, is to bring the more refrangible rays, as the violet, to a focus much sooner than the less refrangible rays, such as the red. This defect, which is most observable in condensing lenses, is called *chromatic aberration.*

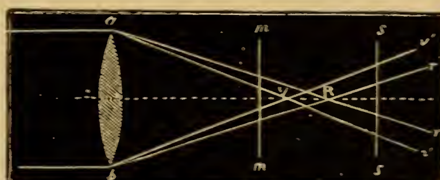


Fig. 50.

Fig. 50 shows the violet rays coming to a focus at V sooner than the red ones at R. If these rays be received on a screen placed at *mm*, within the focus of the violet rays, a bright spot with a red border is seen; if the screen be placed at *ss*, beyond the focus of the red rays, the bright spot has a violet border.

The evil has been overcome very effectually by combining with the convex lens a plano-concave lens of a different substance. The convex lens is usually made of crown glass, and the concave lens of flint glass, as indicated in Fig. 51.

Flint glass disperses light more than crown glass, and corrects the dispersion of the latter without neutralizing all its refraction. A compound lens composed of these two lenses cemented together constitutes what is called an *achromatic lens*. In a similar way, the aberration is overcome in the eye by the combination of convexo-concave, double-convex, and concavo-convex; viz., cornea, lens, and vitreous body.

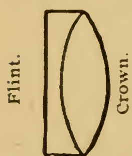


Fig. 51.

CHAPTER III.

THE EYE.

The human eye (Fig. 52) consists, principally, of three investing tunics or coverings, three refractive media, and three chambers. The tunics are:

1. The sclerotic and cornea.
2. The choroid, iris, and ciliary processes.
3. The retina.

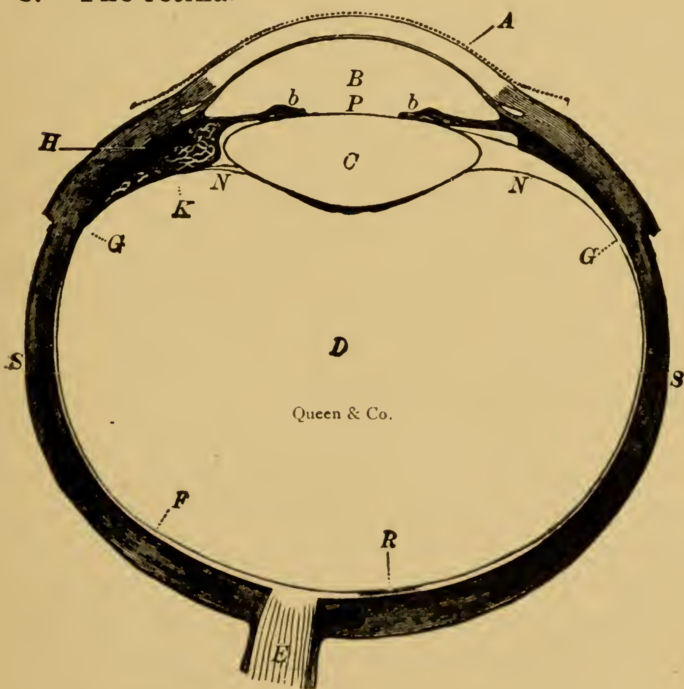


Fig. 52.

The refractive media are:

1. Cornea and aqueous humor.

2. Crystalline lens and capsule.
3. Vitreous body.

The chambers are:

1. Anterior chamber.
2. Posterior chamber.
3. Vitreous chamber.

The *sclerotic* (*S*) and the *cornea* (*A*) form the external tunic of the eyeball; they are essentially fibrous in structure.

The *sclerotic* or *sclera* is opaque and forms five-sixths of the covering of the globe. The *cornea* is transparent, having no bloodvessels, and forms the remaining one-sixth. The sclerotic, from its density and hardness, serves to maintain the form and integrity of the globe.

The *cornea*, the watch-glass or window of the eye, consists of five layers. It has no blood-vessels, but plenty of nerves and lymphatics. It serves to transmit light into the eye. It is convex in front and concave behind. Its curvature varies in different individuals and is sometimes asymmetrical (astigmatic). The cornea also assists in focusing rays of light as they pass into the eye.

The *choroid* (*F*) is the principal part of the second tunic, investing about five-sixths of the globe and consists of two layers, inner and outer. It is the vascular and pigmentary coat of the eye. The *ciliary processes* (*H*) are appendages of the choroid, being developed by a reduplication of its front part.

The function of the choroid is to supply blood to the eye and act as a dark background, absorb-

ing rays of light after they have passed through the refractive media to the retina.

The *iris* (*b*) is a circular, muscular septum composed of circular and radiating fibres with fibrous stroma containing blood-vessels, nerves, lymphatics, and pigmentary cells. It has a circular aperture a little to the nasal side of its center, called the pupil (P). The circular fibres are arranged around the pupillary margin, the radiating extend from the pupillary to the ciliary margin. The iris hangs vertically behind the cornea and in front of the crystalline lens.

The function of the iris is to regulate the amount of light through the pupil to the eye, by the action of its circular and radiating fibres. The circular fibres contract to exclude and the radiating contract to admit light.

The *ciliary muscle* (*K*) is placed at the junction of the sclera, iris, and cornea. This muscle consists of two sets of fibres, meridional and circular. The circular fibres of the ciliary muscle are believed to enter largely into the function of accommodation. (Further attention is given to this muscle under the chapter on accommodation.)

The *retina* (*R*) is the internal or third coat of the eye. It consists of ten layers, some of which are formed by the expansion of the optic nerve, from which the retina extends forward to the ciliary muscle, where it terminates by a serrated margin, the *ora serrata*.

The layers of the retina from without inwards are as follows, as shown in the accompanying cut. (Fig. 53.)

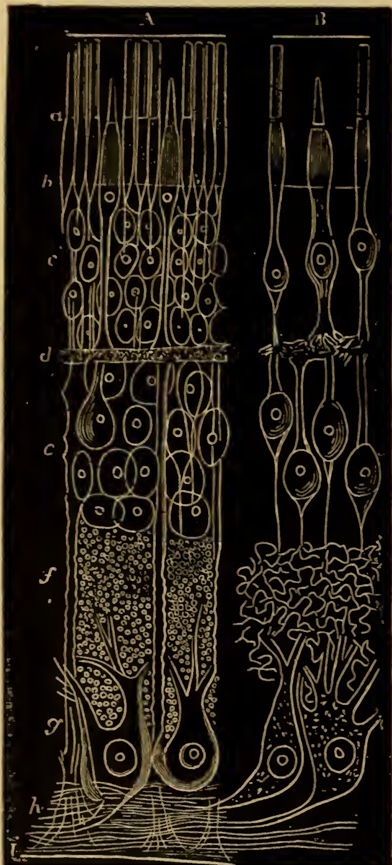


Fig. 53.

1. Pigmentary layer (P).

2. Layer of rods and cones, columnar layer, or Jacob's membrane (*a*).

3. Membrana limitans externa (*b*).

4. Outer nuclear layer (*c*).

5. Outer molecular layer (*d*).

6. Inner nuclear layer (*e*).

7. Inner molecular layer (*f*).

8. Vesicular layer (*g*).

9. Fibrous layer (*h*).

10. Membrana limitans interna (*i*).

Of these, the most important is the columnar layer, or Jacob's membrane. Just at the center of the posterior part of the retina, at a point corresponding to the posterior pole of the axis of vision, about 6 mm. towards the temporal side from the center of the optic nerve, is a yellow spot called the *macula lutea*, or *yellow spot of Sömmerring* (R, Fig. 52). At the center of this spot is a depression known as the *fovea centralis* in which is found only Jacob's membrane where the cones predomi-

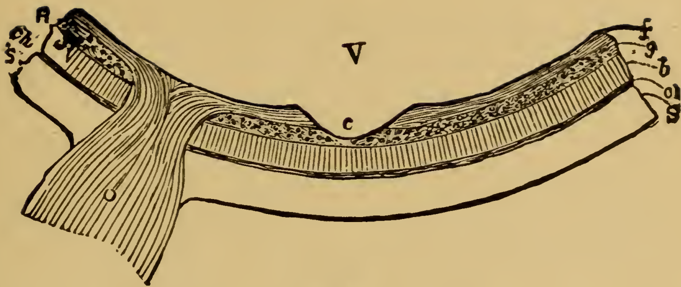


Fig. 54.

nate, as seen in Fig. 54 (*c*). At this point, the sense of vision is most acute.

The space between the iris and cornea is known as the *anterior chamber* of the eye (B, Fig. 52); that between the iris and lens is the *posterior chamber* (L). These chambers are filled with a fluid known as the *aqueous humor*. The two chambers communicate through the pupil.

The large chamber back of the lens is known as the *vitreous chamber*. It contains the *vitreous body* (D, Fig. 52), which forms four-fifths of the entire globe. This body is a gelatinous substance about the consistency of the white of an egg, and is enclosed in a thin, transparent membrane similar to the skin of an egg called the *hyaloid membrane* (G), and fills the vitreous chamber. It is hollowed in front for the reception of the crystalline lens. It is perfectly transparent, and serves to maintain the shape of the globe. It assists in focusing light upon the retina, and is a medium of nourishment to the crystalline lens. In fœtal life it has a canal through its center through which passes the hyaloid artery to the back part of the lens. This artery occasionally remains and is seen after birth.

The *crystalline lens* (C) is enclosed in a cap-

sule, and is situated immediately behind the iris in front of the vitreous body; it is lodged in the concavity of the latter (the *hyaloid fossa*). The lens is a double convex body having its greater convexity on the posterior side. It is perfectly transparent and consists of several concentric layers. It measures about 8 7 mm. in its transverse diameter, and about 3.8 mm. in its antero-posterior diameter, being about the shape of a small plum stone. It is the principal refracting medium of the eye. It is held in place by the *suspensory ligament* (NN), and is acted upon by the ciliary muscle (K).

Fig. 55.

The *optic nerve* (E) does not enter the eye at the posterior pole of the axis of vision, but about 6 mm. to the nasal side of this pole. It serves to transmit impressions to and from the brain. It is unimpressionable to rays of light, and the place of the entrance of the optic nerve is the *blind spot* of the eye. This can be demonstrated by the following experiment:

Cover the left eye, and direct the right eye steadily to the white star in Fig. 55. The circular spot will also be visible, although less distinctly, since it will be out of the direct line of vision (the sensibility of the retina diminishing as the image recedes from the yellow spot). Hold the page vertically at the height of the eyes, and at a convenient distance for seeing both objects in the above manner; now move it slowly backward or forward, and when a certain distance is reached the circular spot disappears, because its image has fallen upon the optic nerve or blind spot. Within and beyond this distance it is again visible.

The eye may be likened to a camera obscura in which the retina serves as a screen or sensitive plate; the choroid as the dark background; the lens, aqueous, and vitreous as the refractive media; and the iris as a diaphragm to cut off those rays that would traverse the lens near its edge and give rise to aberration. The ciliary muscle acts as a sliding tube, or adjustment.

If the two outer coatings are removed from the back part of the eye of an ox, recently killed, so as to render the eye transparent, true images of whole landscapes may be seen formed upon the retina of the eye looked at from the back, as in the kodak.

The focusing of the image of distant or near objects upon the retina is effected by a change of convexity of the lens by means of the ciliary muscle. This change is known as *accommodation.* We can almost instantly change the convexity of the lens so as to form on the retina a distinct

image of an object miles away, or only a few inches distant. The nearest limit at which an object can be placed from the eye and form a distinct image on the retina is about five inches. The normal eye, in a passive state, is adjusted for objects at an infinite distance; as a fixed star (parallel rays), and may be accommodated for objects, as above stated, at a distance of five inches.

DIOPTRIC SYSTEM AND OPTIC AXIS. The refractive media, namely the cornea, aqueous humor, crystalline lens, capsule, and vitreous humor make up the *dioptric system*. These media taken conjointly, act as a bi-convex lens. The axis of the dioptric system is called the *optic axis*, the anterior extremity of which corresponds to the center of the cornea, and the posterior to a point situated between the yellow spot and the entrance of the optic nerve.

VISUAL LINE. The *visual line* is an imaginary

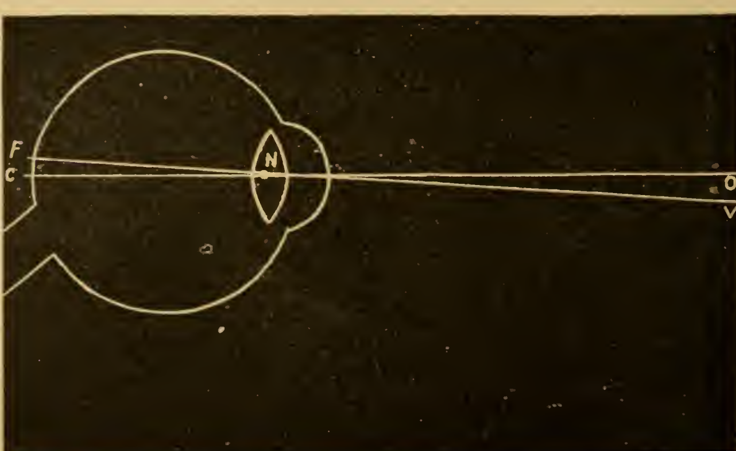


Fig. 56.

OC, Optic axis. F, Fovea centralis. VF, Visual line. N, Nodal point.

line drawn straight from the object through the nodal point N (Fig. 56), to the fovea centralis. It is not identical with the optic axis, and, according to Helmholtz, the visual line in front of the eye lies to the inner side of the optic axis and a little above; while its posterior extremity on the retina lies to the outer and lower side of the optic axis, or at the fovea centralis.

VISUAL ANGLE. The visual angle (AOB and A′O′B′, Fig. 57) is the angle under which an object is seen. It is formed by the secondary axes drawn from the extremities of the object to the nodal point. The larger the object the larger the visual angle, provided the distance be the same. The angle AOB is larger than the angle A′O′B′.

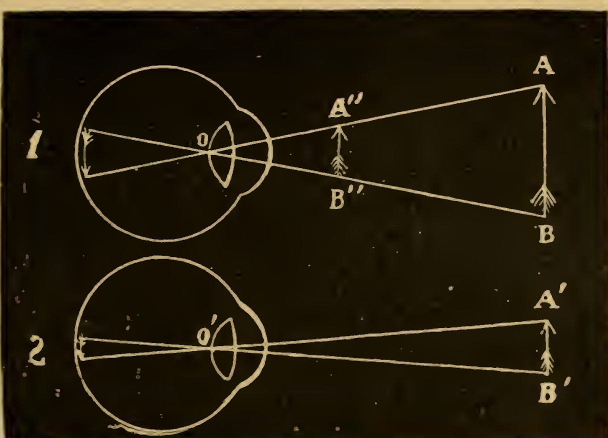


Fig. 57.

An object at a great distance (A′B′) will form a smaller visual angle and hence a smaller image than the same object at a less distance (A″B″); therefore, the greater the distance the smaller will the object appear, and *vice versa*.

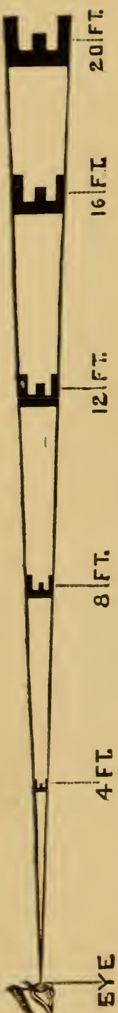


Fig. 58.

Fig. 58 shows that the small E at four feet from the eye is seen under the same visual angle as the large E at twenty feet. This is the case with all intermediate letters; and the retinal image of one is of the same size as that of the others.

The smallest visual angle under which an object can be distinctly seen by the eye is one of 5′ (five minutes), and this has been taken as a standard for determining the acuteness of vision. The test types of Snellen and Giraud-Teulon have been devised upon this principle, each type being seen under an angle of 5′ according to the respective distances; as for instance, No. 1 is seen under an angle of 5′ at a distance of 1 foot. No. 20 under the same angle at 20 feet, etc.

Nodal Point. The nodal point of the eye is just in front of the posterior surface of the lens or where the visual and optic axes cross (N, Fig. 56). The axis ray passing through this point is not refracted; all other rays passing through it form secondary axes.

Optic Angle. The optic angle (BAC and DEF, Fig. 59) is formed by the meeting of the prolongation outwards of the optic axes of the two eyes, the eyes being directed to the same point (fixation point). The angle becomes larger as the fixation point approaches the eyes (the optic axes converging). The angle be-

comes smaller as the fixation point recedes (the

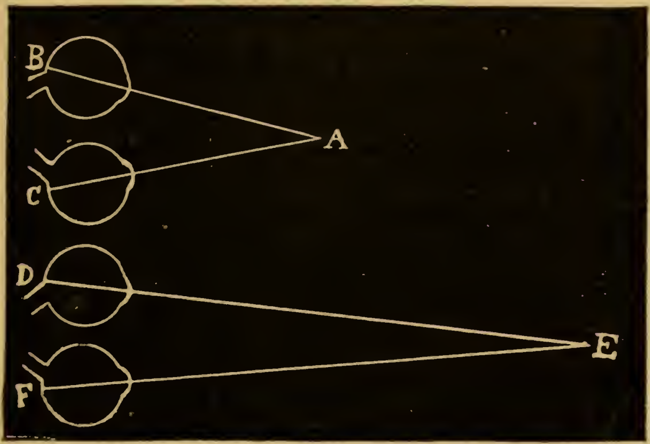


Fig. 59.

optic axes becoming less convergent). Angle BAC is larger than angle DEF (Fig. 59).

CHAPTER IV.

EMMETROPIA AND AMETROPIA.

Emmetropic Eye. An emmetropic eye is an eye that is capable of focusing parallel rays, or those from distant objects, upon its retina without any effort of accommodation; or, in other words, its refraction is such that when the eye is in a state of rest, parallel rays (AA, Fig. 60) are brought to a focus (F) upon its retina. This eye, according to Donders, is the ideal or normal eye (as to its refraction).

If the rays come from a near point (C) they are divergent, and their focus would be at a point behind the retina (D); hence, the power of refraction of the eye must be increased in order to bring these divergent rays to a focus upon the retina. This increased power is brought about by the action of the ciliary muscle, which renders the lens more convex. (See "Accommodation of the Eye," Chapter V.)

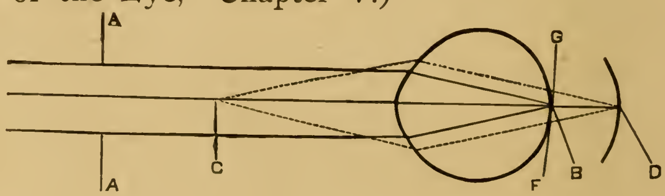


Fig. 60.—Emmetropic Eye.

An emmetropic eye is not necessarily a normal eye, for it may be diseased and nevertheless

be emmetropic; neither is an eye free from disease necessarily emmetropic, as an eye may be ametropic and otherwise healthy.

AMETROPIC EYE. An eye that is not capable of focusing parallel rays upon its retina without an effort of accommodation is called an *ametropic* eye in contradistinction to the emmetropic. This condition is known as *ametropia*, of which we have two forms: *myopia* and *hypermetropia*.

Myopia is that condition of the eye where the focus for parallel rays is in front of the retina.

Hypermetropia, or *hyperopia*, is that condition where this focus is behind the retina.

In the myopic eye parallel rays are united in front of the retina, but rays coming from a near object, being divergent, may be united on the retina.

In myopia the eyeball is either too long or the state of refraction is too high, and rays coming from distant objects, instead of being focused upon the retina, unite at F (Fig. 61), cross and meet the retina as divergent rays, which form circles of diffusion (BB), and so give rise to a blurred and indistinct image of the object.

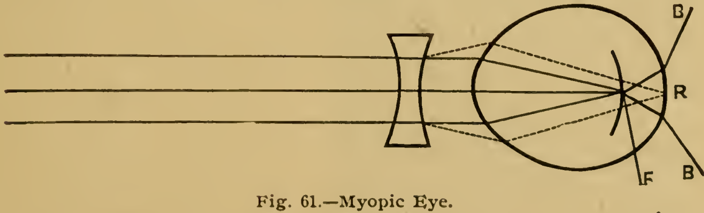


Fig. 61.—Myopic Eye.

In order to render the myopic eye capable of seeing distant objects distinctly, we place a concave lens before it, which diverges the rays, caus-

ing their focus to be further back, or upon the retina, as shown by the dotted lines (Fig. 61).

In the hypermetropic eye, the refractive power is too low, or the eyeball is too short, so that when in a state of rest, parallel rays impinge upon the retina before coming to a focus, thus giving rise to circles of diffusion or blurred images of the objects looked at (Fig. 62).

By placing a convex lens in front of the eye, the rays are rendered convergent before they enter the eye, and so their focus would be at a shorter distance than that of parallel rays, as at the retina. (R, Fig. 62 and *dotted lines*.)

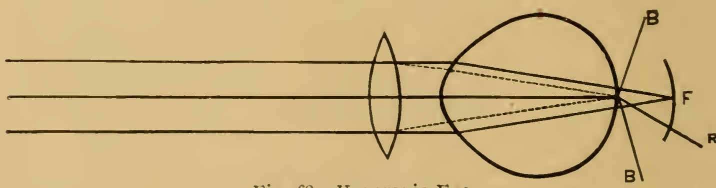


Fig. 62.—Hyperopic Eye.

In an eye of a moderate degree of hypermetropia the same condition may be brought about by the power of accommodation, thus rendering the crystalline lens more convex (Fig. 63, *dotted line*).

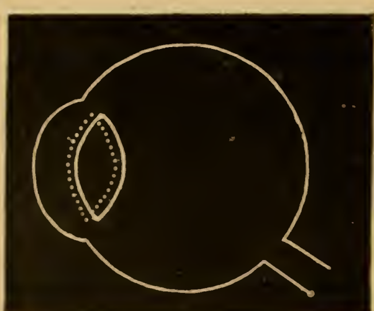


Fig. 63.

ANGLE ALPHA. In the emmetropic eye, the visual line passes through the cornea slightly to the nasal side of its center, and meets the retina at the yellow spot. It crosses the optic axis at the nodal point

(N, Fig. 64) and forms with it an angle of about 5 degrees, which is called the *angle alpha* (angle ONV), and when thus formed by the crossing of the visual line and the optic axis it is said to be *positive*.

Fig. 64.

ANGLE GAMMA. C (Fig. 64) is the center of rotation of the eyeball; angle OCV, formed by the optic axis and an imaginary line drawn from the object of fixation to the center of rotation, is called *angle gamma*.

In the hyperopic eye the visual line lies more to the nasal side than in the emmetropic eye, and the angle alpha increases, being 8 or 9 degrees. In the myopic eye the visual line approaches the optic axis, and may coincide with it, or even lie to the temporal side, when the angle is said to be *negative*. These differences in relation between the optic axis and visual line often give rise to an apparent strabismus, either divergent or convergent, as the visual line lies to the inner or outer side of the optic axis.

ASTIGMATISM. We have seen that in myopia the refraction is too great, while in hyperopia it is too low. This excess of refraction in simple myopia as well as the deficiency in simple hyperopia is of the same amount throughout all the

different meridians of the eye (H, E, M; Fig. 65). There are eyes, however, in which one of the principal meridians is emmetropic, the other ametropic; as for instance, an eye may be emmetropic in its vertical meridian and ametropic in the horizontal, or *vice versa*; or both principal meridians may be ametropic but vary in amount. This inequality of refraction of the eye is called *astigmatism* (rays of light coming from a point and passing through the refractive media are not focused at a point).

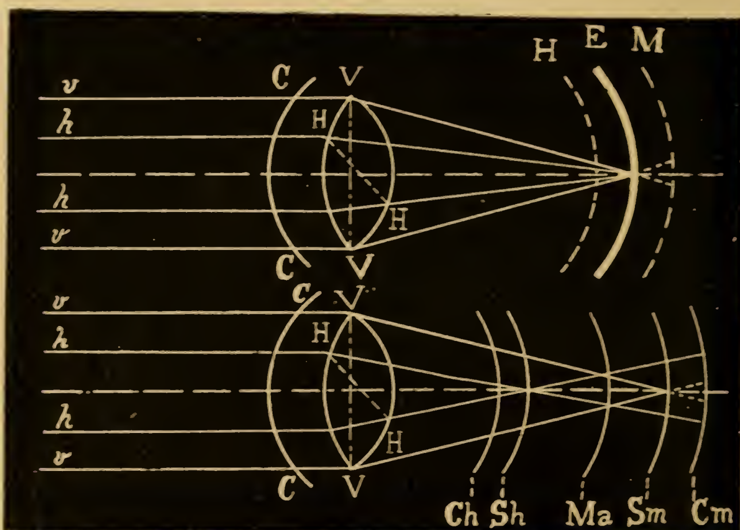


Fig. 65.

If the eye is emmetropic in one meridian and myopic in the other, it is called *simple myopic astigmatism* (Sm, Fig. 65).

If it is emmetropic in one and hyperopic in the other, it is called *simple hyperopic astigmatism* (Sh, Fig. 65).

If it is myopic in one with a greater degree

of myopia in the other, it is called *compound myopic astigmatism* (Cm, Fig. 65).

If it is hyperopic in one with a greater degree of hyperopia in the other, it is known as *compound hyperopic astigmatism* (Ch, Fig. 65).

If it is myopic in one and hyperopic in the other, it is called *mixed astigmatism* (Ma, Fig. 65).

If the eye is ametropic in only a portion or sector of a meridian, the condition is called *irregular astigmatism*, in contradistinction to the forms just enumerated, which come under the head of *regular astigmatism.*. Regular astigmatism can be corrected by glasses; irregular can not.

Astigmatism is due to an asymmetry of curvature of one or more of the refractive media, usually the cornea. It may be of the lens. If of the cornea, it is called *corneal astigmatism;* if of the lens, *lenticular.*

Astigmatism Common to all Eyes. In every so-called emmetropic eye the cornea is not precisely symmetrical in its curvature, being slightly more convex in the vertical than in the horizontal meridian; but the difference is very slight, and it is only where there is an appreciable variation in the curvature that the eye is stigmatized *astigmatic*, and requires a correcting glass.

APHAKIA. An eye deprived of its crystalline lens, as after extraction of cataract, is said to be aphakic; and if it is not of a high degree of myopia, it will require a convex lens to focus rays upon its retina—a stronger one for divergent rays or those coming from near objects, and a

weaker for parallel rays or those coming from distant objects.

ANISOMETROPIA. Occasionally, one eye is emmetropic while the other is ametropic; again, we may have one form of ametropia in one eye, and another form in the other, or we may have the same form of ametropia in both eyes but differing in amount. This we call *anisometropia.*

CHAPTER V.

THE ACCOMMODATION OF THE EYE.

If after looking through an opera or field glass at a distant object, it is desired to view one nearer at hand, it will be found impossible to obtain a clear vision of the latter unless the focus of the instrument is changed. This is effected by means of a screw. If a distant object be looked at by the naked eye through a veil or window screen near the face, it will be found that when the object is clearly seen, the fibres of the veil or wires of the screen are indistinct; and when the veil or window screen is looked at, the object appears blurred; in other words, distant and near objects are not seen with equal clearness at one and the same time.

The eye has the power of adjusting itself for different distances, increasing its refraction when viewing a near object, and diminishing it when looking at a distant object.

This power has been found by exclusion to be lodged in the ciliary muscle and is called the *power of accommodation.*

The ciliary muscle of the eye might be likened to the screw in the opera or field glass; but instead of advancing and retracting the crystalline lens, as does the screw the lens in the opera or field glass, this muscle changes only the anterior portion of the crystalline lens.

The eye, by nature, is adjusted for distant objects, and has to be accommodated for near objects. In the accommodation for near objects the lens changes its convexity and position, especially its front part.

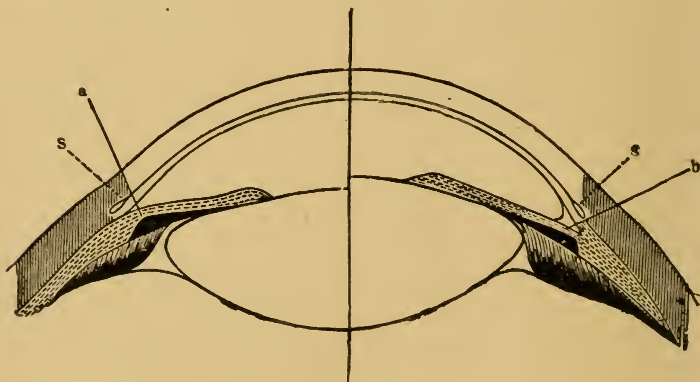


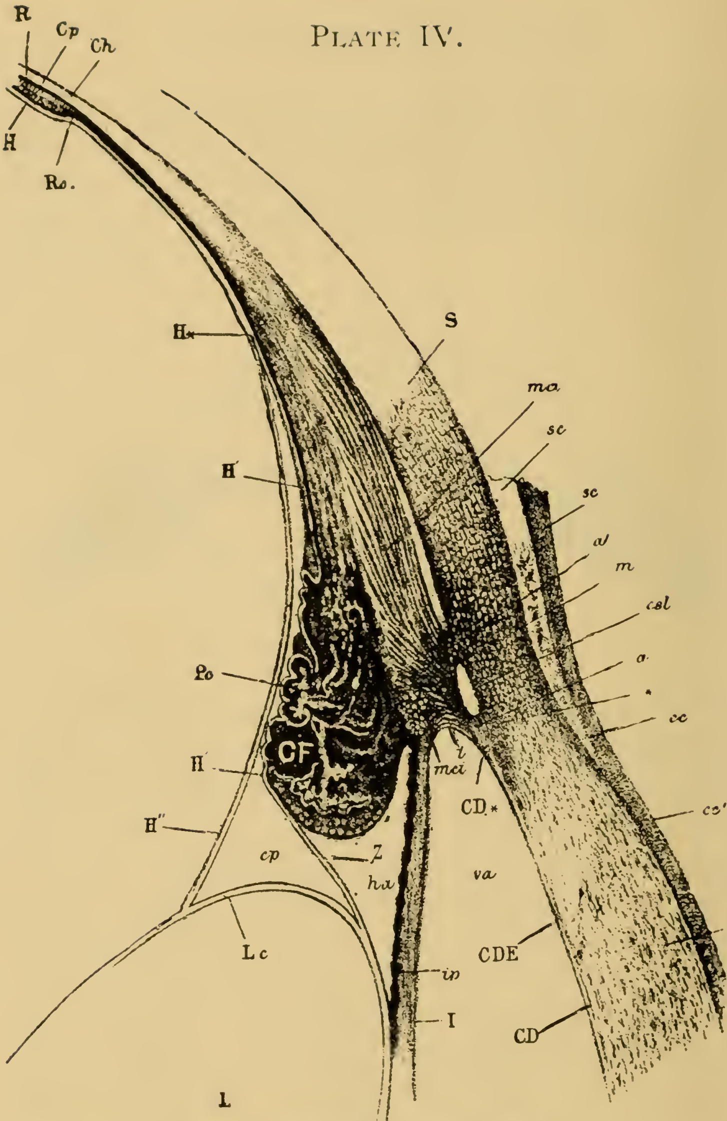
Fig. 66.

In Fig. 66, the left half shows the position of the parts when the eye is adjusted for distant objects; the right half when it is accommodated for near objects.

When the eye is adjusted for distant objects, as shown in the left half of the figure, the pupil is larger, the lens is flatter, and the iris forms a curve (*a*); but when accommodated for near objects the lens advances, advancing the iris, the pupil becomes smaller, the iris is straightened (*b*), and the anterior chamber is lengthened but shallower.

In speaking of the anatomical structure that is brought especially into requisition in the power of accommodation, the *ciliary body* is the principal part; and this consists of two sets of fibres, *circular* (CF, Plate IV) and *radiating* (*ma*), besides the *zone of Zinn* (H′), and ciliary processes (P*c*).

Plate IV.



Anatomy of the ciliary region (Wells).

R, Retina.
H, Hyaloid.
Ro, Ora serrata.
Cp, Pigment layer of choroid.
Ch, Choroid.
H*, Place of division of hyaloid.
H', Zonula.
Pc, Ciliary processes.
H", Posterior layer of hyaloid.
CF, Circular fibres of ciliary muscle.
Z, Free portion of zonula.
cp, Canal of Petit.

Lc, Capsule of lens.
L, Crystalline lens.
ha, Posterior chamber.
va, Anterior chamber.
S, Sclerotic.
sc, Vascular layer of connective tissue of the sclerotic conjunctiva.
sc', Its epithelium.
mci, Meridional fibres of ciliary muscle.
a, External fibres of membrane of Descemet.
m, Middle fibres.
i, Internal fibres, or ligamentum pectinatum iridis.

csl, Canal of Schlemm.
C, Cornea.
cc, Its anterior elastic lamina.
cc', Epithelium of the anterior surface of the cornea.
CD, Membrane of Descemet.
CD*, Place of division of membrane of Descemet.
CDE, Epithelium of membrane of Descemet.
I, Iris.
ip, Pigment layer.

The ciliary body is intimately connected with the cornea (C), sclera (S), iris (I), choroid (C*h*), and retina (R). The radiating or meridional fibres blend anteriorly with the cornea and the ligamentum pectinatum iridis (*i*), and posteriorly with the sclera; while the circular fibres are more intimately connected with the iris, suspensory ligament (zone of Zinn), hyaloid membrane (H), and choroid; in fact, they are a part of the choroid.

The ciliary body is anchored at the limbus, or junction of the cornea with the sclera. The meridional fibres enter largely into the formation of the walls of the circular venous canal, or canal of Schlemm (*csl*).

The zone of Zinn is a continuation of the hyaloid membrane which bifurcates a few mm. posterior to Schlemm's canal (at H*), the anterior portion traversing the ciliary body and passing around the front part of the lens, the posterior around the back part. Between the two layers and the lens is a triangular space traversed by fibres of both the anterior and the posterior portions of the zone of Zinn, producing an open meshwork or lacunæ, similar to the spaces of Fontana (*f*, Fig. 69). This space has been designated the *canal of Petit* (*cp*). The posterior layer of the zone of Zinn is intimately connected with the retina at the ora serrata (R*o*).

The *ciliary ligament* is a narrow band of fibres encircling the iris at the junction of the cornea and sclera, to which is anchored the ciliary body by an intimate interlacing of the meridional fibres of the ciliary muscle.

The *ciliary processes* (P*c*) are from seventy to eighty in number. They constitute the inner portion of the ciliary body and are arranged in the form of a crown. In this crown is suspended the crystalline lens (L), which is held in place by the zone of Zinn (H″ and Z).

The ciliary muscle is largely supplied by the ciliary nerves, which are very numerous and pass through the ciliary region to the cornea. The ciliary body is highly vascular; it is, in fact, largely composed of arteries, arterioles, veins, and venules, with a meshwork of pigmentary cells.

The change in the form of the lens during accommodation has been considered to be due chiefly to the action of the circular fibres of the ciliary muscle (the movement of the iris being an associated movement).

The conclusions in regard to accommodation according to Heinrich Müller are the following:

1. "The circular fibres of the ciliary muscle exert a pressure upon the edge of the lens by means of which the latter becomes thicker.

2. "The longitudinal fibres of the muscle cause an increase of tension in the vitreous humor on account of which the posterior surface of the lens is prevented from shifting, and the action of the peripheral pressure is chiefly confined to the anterior surface.

3. "The pressure of the tense iris on the peripheral portion of the anterior surface of the lens probably assists in increasing the convexity of the latter.

4. "The arching forward of the center of the anterior surface of the lens is rendered possible and favored by the recession of the peripheral portion of the iris, which is accompanied by a contraction of the deeper (circular) layer of the ciliary muscle and the iris.

5. "The contraction of the ciliary muscle causes finally a relaxation of the anterior portion of the suspensory ligament, by which means, again, the increase in thickness of the lens is promoted."

It was formerly thought that the iris played an important part in the power of accommodation, but this was definitely disproved by a case in Von Græfe's clinic in which the iris was entirely removed without disturbing in the least the power of accommodation. Also in congenital cases where no iris is present, the accommodation may be perfect.

That the convexity of the anterior surface of the lens increases during accommodation for near objects may be proved by the "catoptric test," which is made as follows:

Let a person in a room with dark walls direct his eye to some distant object and have a candle flame at one side of the eye so that its rays fall somewhat obliquely upon the cornea, say at an angle of about 30 degrees with the line of sight. The candle should be about 14 inches distant from the eye. If the observer place himself on the opposite side of the person observed, also at an angle of 30 degrees, three reflected images of the flame will become visible in the pupil, as in Fig. 67 (A).

The first image (*a*) is the brightest and is re-

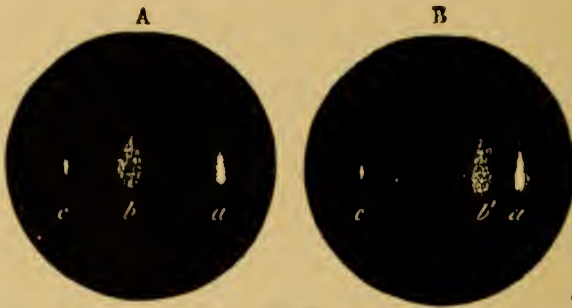
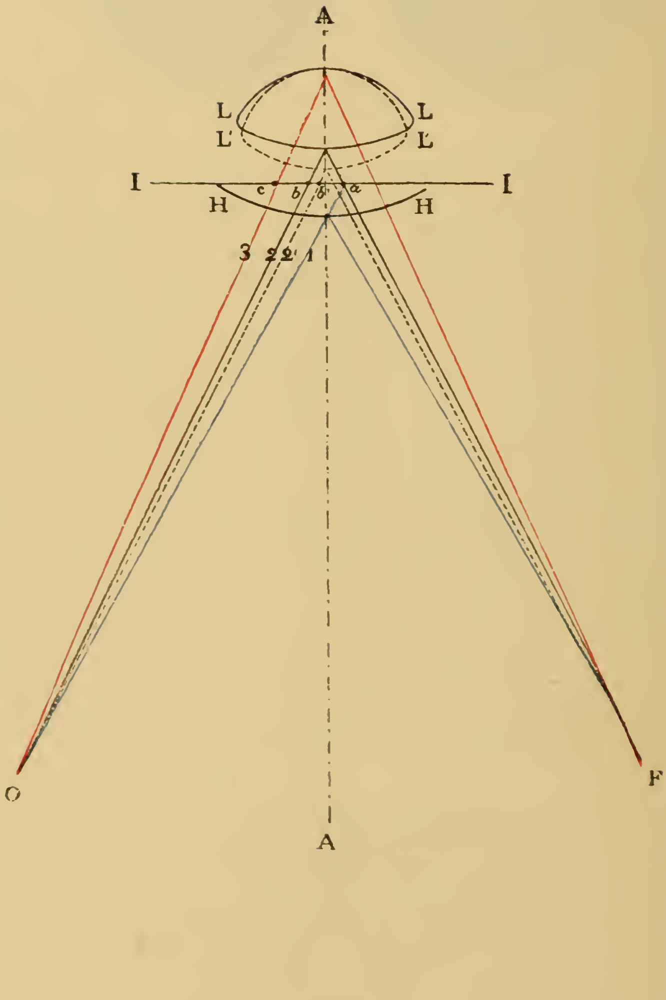


Fig. 67.

flected from the cornea which acts as a convex mirror. It is virtual and erect. The second (*b*) is also erect and virtual, but is much fainter, and is reflected from the convex anterior surface of the crystalline lens, which also acts as a convex mirror. The third (*c*) is smaller, dim, real, inverted, and is reflected from the anterior surface of the vitreous humor, which acts as a concave mirror. If the person under observation now change his point of sight from the distant to a near object, the eyeball remaining fixed, the second image (*b*) becomes smaller, and places itself nearer the first (*b'*). This indicates that the anterior surface of the lens becomes more prominent, and approaches the cornea; but there is no change in the other two images, showing that the curvatures of the cornea and of the posterior surface of the lens remain unaltered.

In Plate V, AA is the axis of the cornea and of the lens. The continuous lines of the lens show its form when adjusted for distant objects; the dotted lines show the form when accommodated for near objects. At F is the flame, and at O the eye of the observer. These two are so placed that lines proceeding from them form equal

PLATE V.



angles with the axis when intersecting it at the same point. Therefore, the image of the flame reflected from the cornea is seen in the direction O1, that from the anterior surface of the lens in the direction O2, and that from the posterior surface in the direction O3. These images projected on the surface II are seen as *a*, *b*, and *c*, as shown in the preceding figure (67, A). If the person under observation now change his sight from the distant to a near point, the anterior surface of the lens advances, as shown by the dotted lines, the second image is seen in the direction O2′ and projected on the surface II appears at the point *b*′, and has approximated the image *a* reflected from the cornea. This has also been observed in the preceding figure (B).

The advance of the iris from protrusion of the anterior face of the lens in accommodation for near objects can be observed by looking into the eye from the side. The person under observation looks at some distant object, and the observer places himself in such a position that the edge of the iris is just concealed by the sclerotic. If the sight be now changed from the distant object to a nearer one in the same line of vision, the iris becomes visible a little in front of its former position. If the sight be again directed to the distant object, the ciliary edge of the iris disappears behind the sclerotic.

It has been claimed by some that there is an active accommodation for distant objects, but at the present time it is believed that accommodation for distant objects is passive, while that for near ob-

jects is active. The lens enclosed in its capsule is composed of elastic tissue, and possesses a high

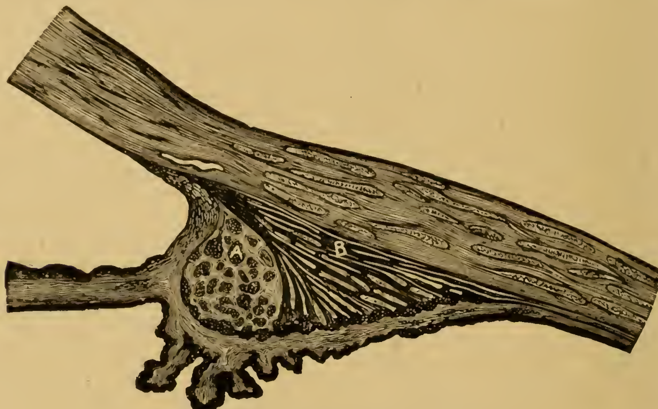


Fig. 68.—Hyperopic Eye. (Iwanoff.)

degree of elasticity, by virtue of which it regains its normal form as soon as the pressure in the act of accommodation is relieved. Therefore, we con-

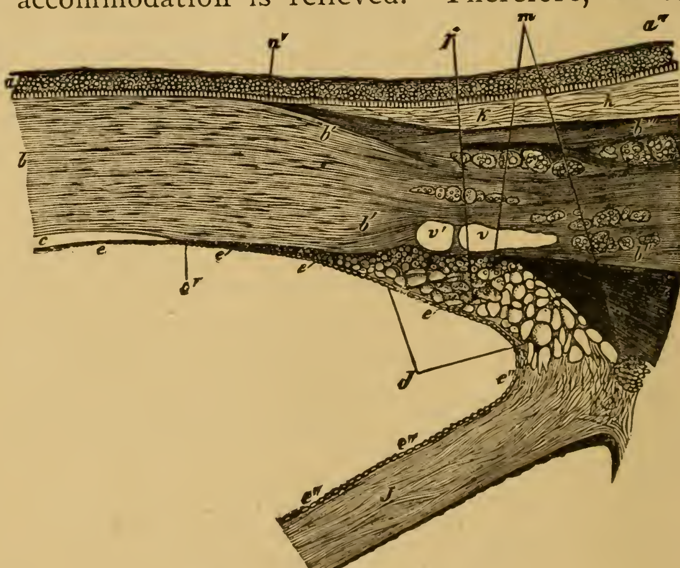


Fig. 69.—Emmetropic Eye. (Iwanoff.)

clude that the change in the form of the lens dur-

ing accommodation for near objects is due to active muscular force, while that for distant objects is a spontaneous reaction.

Frequently, however, when looking at objects in the far distance, they are seen only very dimly; but by putting forth a great effort, looking intently, they finally come more distinctly into view. This would suggest an active muscular power for distant objects, or an increased retinal receptivity.

We have seen that the circular fibres of the ciliary muscle play the most important part in the function of accommodation, and they predominate in the hyperopic eye (Fig. 68) where the power of accommodation is constantly brought into use, whether the person is looking at near or distant objects. Fig. 69 shows the normal condition of the eye at the ciliary region; *vv'*, Schlemm's canal; *f*, Fontana's spaces; *b*, the cornea; *J*, iris; *d*, ligamentum pectinatum iridis; *m*, ciliary muscle; *a'*, epithelial layer of the cornea.

Fig. 70.—Myopic Eye. (Iwanoff).

In the myopic eye where there is little or no demand for the power of accommodation, the circular fibres are almost wanting, as seen in Fig. 70.

When the ciliary muscle is relaxed to its utter-

most, the lens has assumed its least convexity, and the eye is then adapted for its far point (*punctum remotum*).

When in this condition the eye is spoken of as being in a state of complete repose.

When the circular fibres of the ciliary muscle have contracted as much as they can, the lens has assumed its greatest convexity, and the maximum amount of accommodation is in force; the eye is then accommodated for its nearest point. This is called the near point (*punctum proximum*).

In the emmetropic eye the punctum remotum is situated at infinity. The position of the punctum proximum may be ascertained by noting the shortest distance at which the person can read No. 1 of the small test type with each eye separately. (See test type, appendix.)

In normal eyes the nearest point of distinct vision lies at about four or five inches from the eye. This varies according to the age of the person, the point receding from the eyes with advancing years, or the waning of the power of accommodation, beginning at the early age of ten; at the age of seventy-five, the power of accommodation is *nil*.

For continued work at near objects, engraving, etc., the near point lies at about five inches. The furthest point of distinct vision in the normal eye is at an infinite distance. The distance between the punctum remotum and the punctum proximum is called the *territory* or *range of accommodation*. The greater this range, the more evidence of accommodative power.

Static Refraction is the refraction of the eye without the active accommodation; that is, when the accommodation is at rest, or when the eye is adjusted for distant objects.

Dynamic Refraction is the additional refraction of the eye when the accommodation is brought into requisition, or when the eye is adjusted for near objects. If the maximum amount of dynamic refraction is exerted, the eye is adjusted for the punctum proximum. The sum of the dynamic and the static equals the maximum refraction of the eye.

The difference between the maximum and the static refraction is the *amplitude of accommodation*, which is, in reality, the dynamic refraction. We thus have the formula $a=m-s$ in which a represents the amplitude of accommodation, m the maximum refraction, and s the static refraction.

MECHANISM OF ACCOMMODATION.

The crystalline lens, in its normal state, is of an elastic nature and if uncontrolled tends to approximate the spherical form; it, however, is under the control of the suspensory ligament, or zone of Zinn, which is tense when the eye is in a state of rest or adjusted for distant objects. By the contraction of those fibres of the ciliary muscle which encircle the lens (the so-called circular fibres), the suspensory ligament becomes relaxed and the lens is allowed to assume a greater convexity, especially its anterior surface, and to advance towards the cornea.

As a further proof of the change in the convexity of the lens during the accommodation of the eye for near objects or divergent rays, we may

mention the experiments of Hensen and Voelckers on the lower animals, as the dog, cat, monkey, etc. They removed a part of the sclerotic in the ciliary region and thereby were able to perceive the contraction of the ciliary muscle which drew the choroid towards the cornea (the fixation point of the ciliary body). These experimenters also placed pins perpendicularly into the different parts of the choroid, and they noticed that the free ends of the pins swayed backwards as the ciliary muscle contracted, which shows that the choroid is advanced by the contraction of the ciliary muscle. They also introduced needles through the cornea and sclera, the point of the former resting on the anterior surface of the crystalline lens, and that of the latter on the posterior surface of the lens (Fig. 71). Then upon electrizing the ciliary muscle, the free extremity of the anterior needle was carried backward, while that of the posterior needle was carried slightly forward. This would show that the change of convexity of the lens in the act of accommodation is not entirely confined to its anterior surface.

Fig. 71.

Coccius noticed in patients with a large peripheral iridectomy, also Prof. Hjort, of Christiania, in a traumatic case where the iris was entirely removed without injury of vision or accommodation, that in the contraction of the ciliary muscle not only the choroid, but the retina advanced.

In studying the anatomy of this region and the mechanism of accommodation, one must observe how intimately associated is this ciliary body with the other parts of the eye, and the vast influence it has in producing the various affections and diseases, especially those peculiar to the uveal tract as well as those of the retina; and we may also fully appreciate the great comfort and relief experienced when this power of accommodation is set at rest by a mydriatic, or relieved by the proper glass correcting the anomaly of refraction or accommodation.

That a large per cent of headaches, so-called migraine, ciliary neuralgia, and even *tic douloureux* with many of the different forms of chorea, of hysteria, of mania even, is due to some anomaly of refraction or accommodation, is recognized by the profession at large; and these patients, instead of haunting the doctor's office for many months or years, receiving little or no benefit, are now readily relieved by the scientific adjustment of glasses; thus, these glasses are not only permanently curative, but they prevent more serious troubles, such as high degrees of myopia, detachment of the retina, choroiditis, choroido-retinitis, neuro-retinitis, glaucoma, nervous prostration, hysteria, chorea, etc.

CHAPTER VI.

HOW TO EXAMINE THE EYE.

It is said that any one can administer treatment in disease if he knows the disease, and "there's the rub," for to know the disease—in other words, to correctly diagnosticate—one needs not only to be familiar with the symptoms in their various forms, but he must carefully examine; and to examine carefully he must not only have the necessary means of examination and various tests, but he must know how to employ them.

Successful physicians, to whom we look for accurate knowledge, from whom we gain valuable statistics, and who become eminent in the profession, keep a full and accurate account of all cases brought under their notice. The doctor should record the name, age, nationality, birthplace, occupation, residence, color of eyes, temperament of each one of his patients, and then the history as gotten from the patient himself, if possible, not from the attendant. In many cases, as with children, the history has to be obtained from the parent or attendant. You may ask, Why take the color of the eyes and the temperament? Certain diseases seem to be peculiar to individuals of a certain temperament and color of the eyes.

After having recorded the name, age, nationality, occupation, residence, history, etc., of the

patient, proceed to examine the eyes, and record the amount of vision without, and then with the glasses. The principal test is that with the glasses from the trial case. (Fig. 72.)

TEST WITH TRIAL LENSES FROM TRIAL BOX. The ordinary box of trial glasses (Fig. 72) contains

Fig. 72.

thirty pairs of spherical convex and thirty pairs of spherical concave glasses, ranging from 0.25 D. to 20 D.; eighteen pairs of cylindrical convex and eighteen pairs of cylindrical concave, ranging from 0.25 D. to 6 D.; twelve prisms from 1° to 20°; some plain tinted glasses—red, green, blue, and smoked; stenopaic discs with slots of various widths (A, Fig. 73), also one disc with a circular opening (B); an

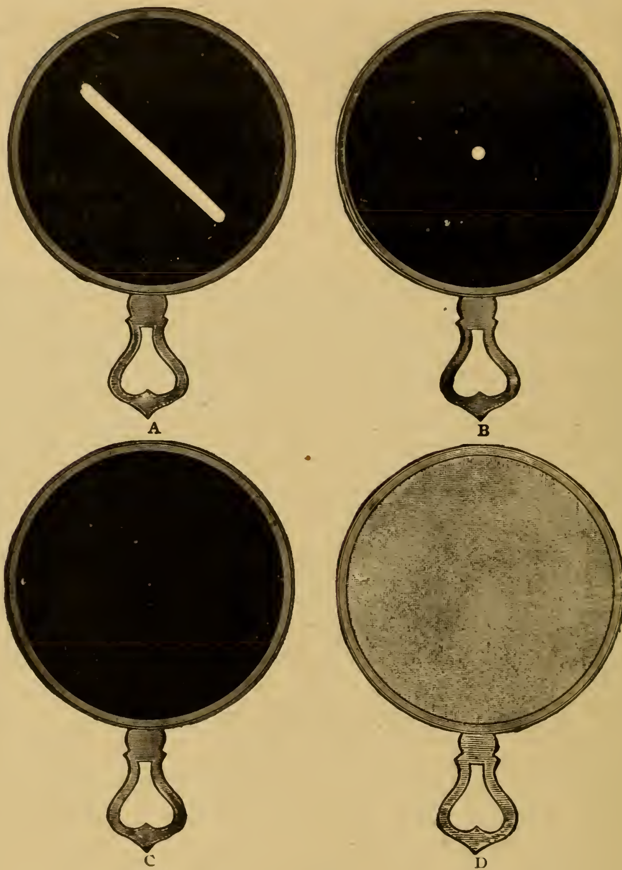

A
B
C
D

Fig. 73.

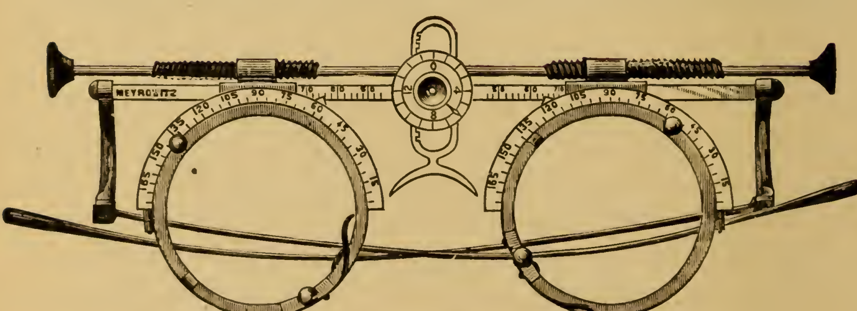
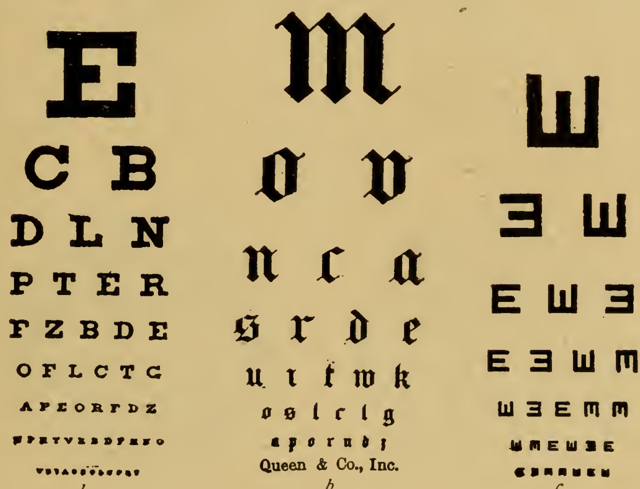

165 150 135 120 105 90 75 60 45 30 15
165 150 135 120 105 90 75 60 45 30 15

Fig. 74.

opaque disc (C); a ground glass (D); and trial frames (Fig. 74), usually two pairs. To make the case more complete there should be a double prism for testing the strength of the muscles (A, Fig. 75), as in heterophoria; a half-ground glass (B); a chromatic glass (C); and a disc with a rod which acts as a strong cylinder (D).

In employing this test, first ascertain the amount of vision of each eye separately. Place the patient at twenty feet from Snellen's test type (*a*,



Snellen's Test Type.

b, or *c*), and see how far down the card he can read the letters. If he is unable to see the largest letter or character at twenty feet, lessen the distance between him and the card, stopping as soon as the largest letter comes into view: If the patient sees only the largest at ten feet, while he should see it at two hundred feet, his vision is ten two-hundredths. In testing for myopia, begin with weak concave glasses placed in the trial frames (Fig. 74), covering the eye not under test

with an opaque disc (C, Fig. 73). If, for instance, you begin with a —0.25, —0.50, or —1 D., and

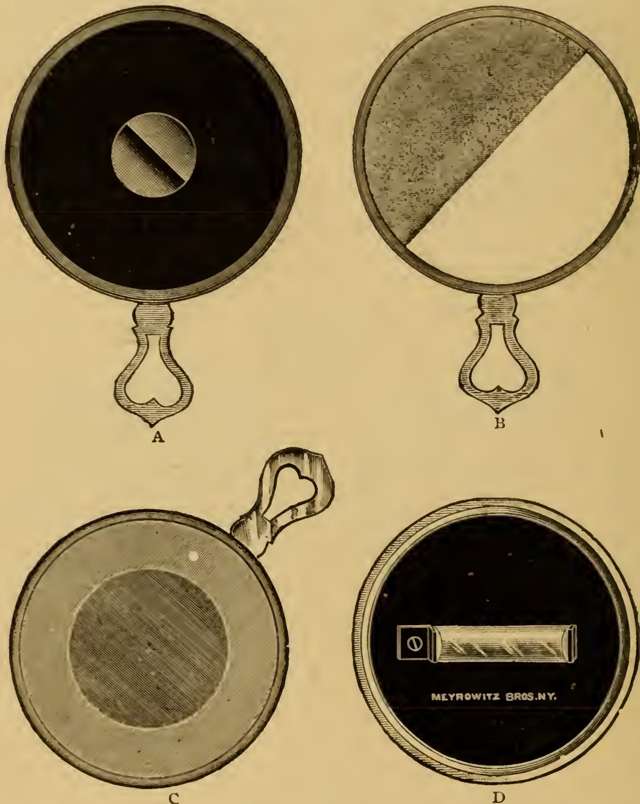


Fig. 75.

this glass improves vision but slightly, try a stronger one, say —1.50 D., or —2 D., and so on until the greatest amount of vision possible is obtained by the glass. If there is a high degree of myopia, we do not expect to obtain, as a rule, twenty-twentieths, or perfect vision. If the amount of myopia is 10 D. or 15 D., frequently vision can not be brought to more than twenty-fiftieths. The weakest glass that gives the correction or

the highest amount of vision should be chosen; it is always best to under-correct slightly than to over-correct; for instance, if a —6 D. will give twenty-fortieths, and it requires a —8 D. or —10 D. to get twenty-thirtieths, —6 D. should be prescribed, rather than the higher number. If the glass is too strong, it brings into requisition the power of accommodation and produces muscular asthenopia, with liability to more serious complications.

If a convex glass improves vision for distant objects, hyperopia exists. Occasionally, a weak concave glass will also improve the vision in the hyperopic eye if there be spasm of accommodation; then a mydriatic may be necessary to reveal the real, true conditions.

In testing for hypermetropia, each eye should be examined separately, as in myopia. Ascertain the amount by the strongest convex glass that will give the greatest amount of vision, which should be the glass prescribed. In hypermetropia there is always a certain amount of latent defect which subsequently will become manifest and a stronger glass will have to be prescribed.

Frequently, astigmatism is associated with myopia or hyperopia, and must be corrected by sphero-cylindrical glasses. The subject of astigmatism, however, will be carefully considered in Chapter IX.

In testing the eyes, the examiner should ascertain for himself the true condition of vision, and not depend upon the statement of the patient; especially is this true with certain individuals. If

you ask them whether they can see all the letters on the card, they will turn to you with an inquiring and almost injured look, and peremptorily declare that they can read every letter on the card; but if you screen one eye by the opaque disc and ask them to begin with the largest letter and read down, it is frequently found that they are unable

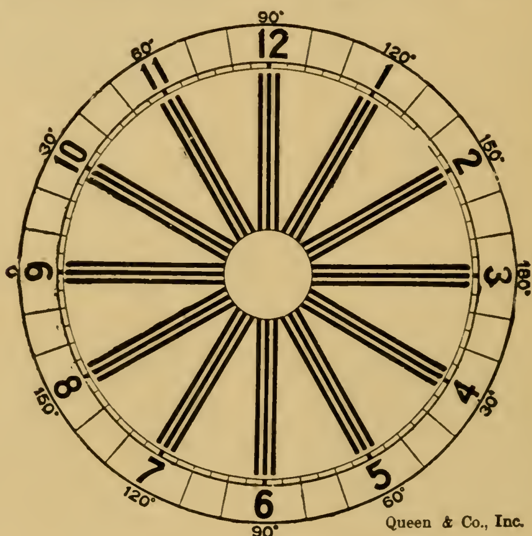


Fig. 76.

to call the letters correctly more than one-half to two-thirds down the card, showing that their vision is perhaps not more than twenty-sixtieths or twenty-fortieths; and even if they are able to see some of the letters further down, they will miscall others, indicating astigmatism.

To detect the presence of astigmatism, have the patient view the dial (Fig. 76) from a distance of twenty feet, and ascertain if he is able to see the lines, one set equally as well as another. If he is astigmatic, the lines in some special meridian will

appear less distinct than in others, and this will indicate the meridian of astigmatism.

To proceed with the examination, place a disc with a slot (Fig. 77) before the eye, rotate the slot into the meridian through which he can get the greatest degree of vision. If through this meridian he has perfect vision, say $\frac{20}{20}$, then turn the slot to the opposite meridian. If it is the 90th that the vision is $\frac{20}{20}$, turn it to the 180th—here, perhaps, it may only be $\frac{20}{80}$, or more or less; then find the concave or convex glass that will give the highest amount of vision; if a concave glass, it is myopic astigmatism; if a convex glass, it is hyperopic astigmatism. If it be a case of compound astigmatism, both principal meridians are ametropic and will require a glass of different strength. If, for instance, when the slot is turned to the 90° a glass of one dioptre is required to get $\frac{20}{20}$, and in the opposite two dioptres, then we have hyperopia of one D. and hyperopic astigmatism of one D., requiring a spherical glass of one D. and a cylindrical glass of one D., with the axis of the cylinder in the 90th meridian.

Fig. 77.

A case of mixed astigmatism can be worked out in like manner. If a convex glass improves vision when the slot is turned to the 180th meridian, and a concave improves when it is turned to the 90th, it is a case of mixed astigmatism with

hyperopia of the 180th meridian and myopia of the 90th, as in the following hypothetical case:

We have 2 D. of hyperopia in the 180th meridian and 5 D. of myopia in the 90th. This might be corrected by giving crossed cylinders with the axis of each cylinder in the meridian we do not

Fig. 78.

wish to affect by the glass; for instance, place a + 2 D. cylinder with the axis in the 90°, and a —5 D. cylinder with the axis in the 180°. Mixed astigmatism is usually corrected by a sphero-cylinder; as, in the above case, spherical +2 D. combined with a cylinder —7 D., with axis in the 180°, might be prescribed; or we could use a spherical —5 D. combined with +7 D. cylinder, axis of cylinder in the 90°.

In prescribing glasses, the pupillary distance should be taken, and the glasses properly centered. A pupillometer (Fig. 78) for this measurement is convenient.

MEASUREMENT OF THE EYE BY THE KERATOSCOPE. The keratoscope (Fig. 79) is an instrument for measuring or examining the cornea. It was invented by Placido, and presents an easy method of determining if there is astigmatism of the cornea or not.

The instrument is quite simple, consisting of a card with several concentric rings and a circular opening in the center.

Fig. 79.

If the card with rings be held before the patient's eye, with his back to the light, the rings can be seen through the opening of the card reflected from the cornea; a convex lens of about 10 D. may be placed behind the card. If the cornea is symmetrical throughout its various meridians, the circles will appear circular, as on the card. If there is astigmatism, they

will be oval, and the direction of their longest diameter will indicate the meridian of astigmatism. The cylindrical glass that renders the ovals circular will indicate the amount of astigmatism. This little instrument is a ready means of detecting and determining the amount of corneal astigmatism.

Fig. 80.

EXAMINATION BY THE PRISOPTOMETER. This instrument (Fig. 80) consists of a revolving double prism set in a large disc, divided by meridians of ten degrees apart, with indicator. There is a circular opening at the center of the instrument in which the prisms which have the effect of doubling objects looked at are set; and a white disc of four inches in diameter, as shown in Fig. 82, seen at a distance of sixteen feet, is doubled, and if the person be emmetropic, the edges are tangent, as seen in *a* (Fig. 81). If the eye is myopic, the discs, instead of being tangent, overlap each other (*b*), requiring a minus glass placed in the instrument to separate them so that their edges merely touch. This glass indicates the amount of myopia. If the

eye is hyperopic, the discs will separate from each other (c), and the amount of hyperopia can be approximately ascertained by the strongest convex glass placed in the clip required to make the two images tangent.

If the prism in the instrument is turned, one disc revolves around the other, and if there is simple myopia or hyperopia, the images will maintain the same relative position all the way around. If there is astigmatism, they will lap or separate according to the kind—myopic or hyperopic.

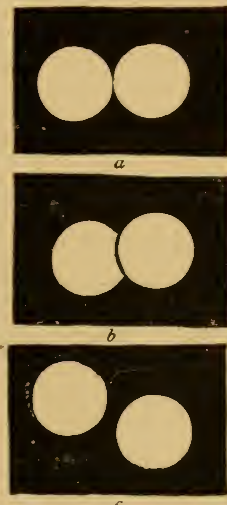


Fig. 81.

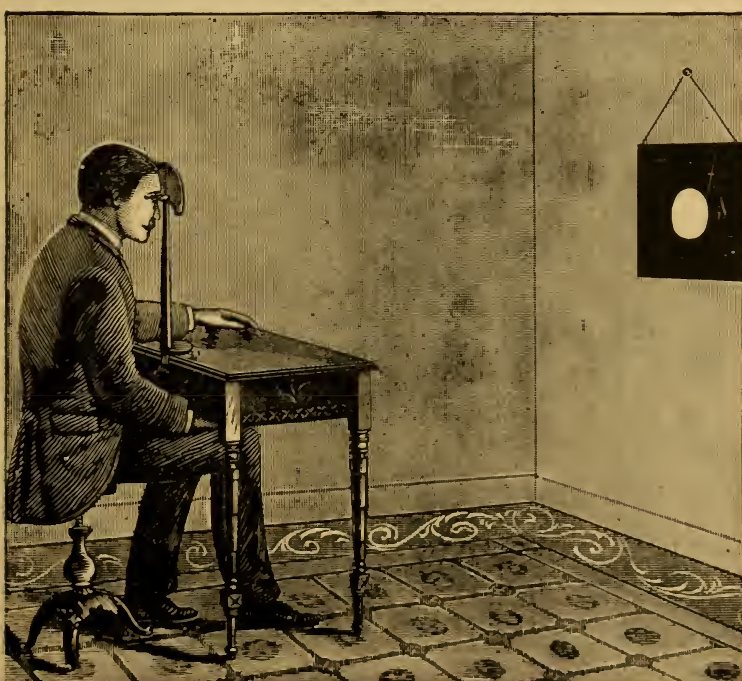


Fig. 82.

EXAMINATION OF THE EYE BY THE OPHTHALMOSCOPE. As a corroborative test, the patient should be examined in a darkened room by the ophthalmoscope.

By this instrument we employ three methods of illumination; namely, *oblique*, *direct*, and *indirect*.

Oblique Method. By the *oblique*, or *focalization*, take a convex lens of two-inch focal power, and

Fig. 83.

focus a pencil of light upon the cornea and front part of the eye (Fig. 83). Place the patient in a chair with gas-light on a level with the pupil, and

about fourteen inches to one side, and a little in front of the patient. By focusing the light, thus causing it to flit over the front of the eye, any slight opacity of the cornea that may have escaped the naked eye is quickly discerned. By this examination, time is frequently saved, as these slight opacities simulate ametropia.

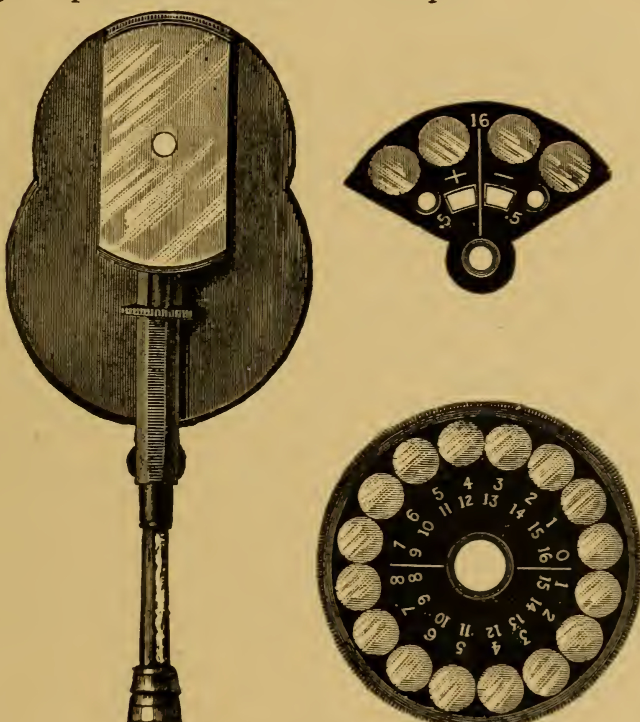


Fig. 84.

The ophthalmoscope was given to us by Helmholtz in 1851, and up to the present time it has proven the greatest boon to ophthalmology. This instrument, especially in lower forms of ametropia, is one of the most reliable tests. For detecting and ascertaining the kind and amount of ametropia, Loring's ophthalmoscope (Figs. 84

and 85), or a modification of this instrument, is the best. If we wish to recognize merely the anomalies and illuminate the fundus, Liebreich's ophthal-

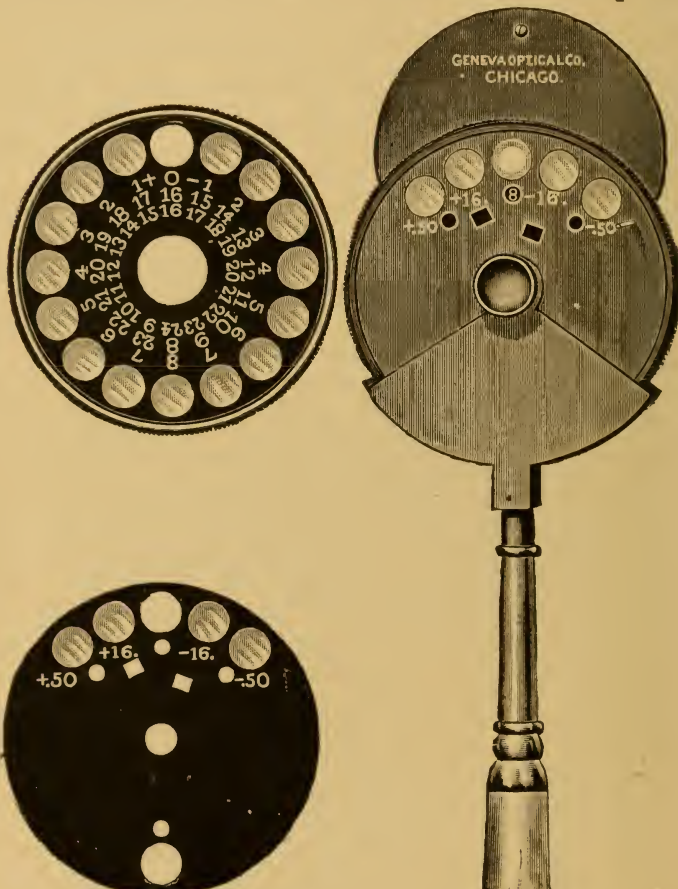


Fig. 85.

moscope (Fig. 86), which is a much cheaper instrument, will suffice.

Loring's ophthalmoscope contains a tilting mirror and a large disc with a series of convex glasses on one side and concave on the other, with a zero between. The convex glasses range from 1 D. to

7 D., the concave from 1 D. to 8 D. These can be rotated in front of the opening in the mirror. Besides the large disc, there is a segment of a disc containing a convex glass of 0.50 D. and one of 16 D., also a concave 0.50 D. and a concave 16 D. By adding the 0.50 to those of the large disc, we can readily get one or more whole dioptres with a half dioptre. With the plus 16 D. in front of the opening, we can, by rotating

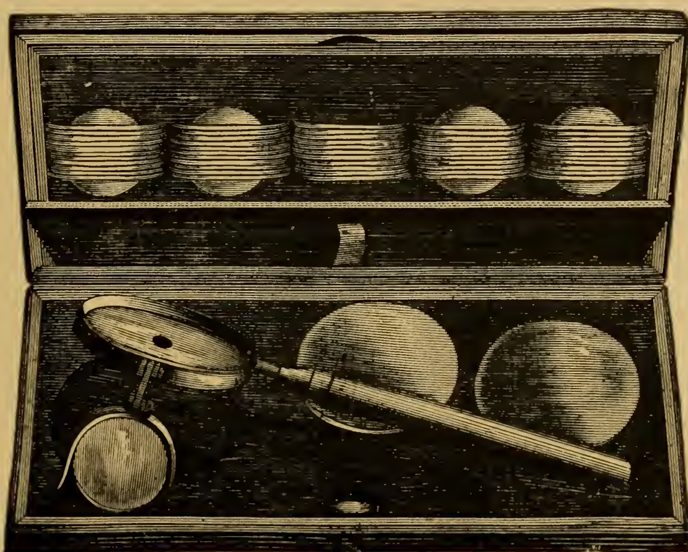


Fig. 86.

the convex lenses in the large disc, get as high as 23 D. With the minus 16 D. in front of the opening, we can gain as high as 24 D. in a concave glass.

The ophthalmoscope with the tilting mirror is an advantage, especially in determining the kind and amount of ametropia, as in this case you can hold the ophthalmoscope perpendicularly in

front of the eye, and the light is reflected into the eye through the opening or sight-hole, with the lens behind it at right angles. The old-fashioned ophthalmoscope (Liebreich's) must be tilted

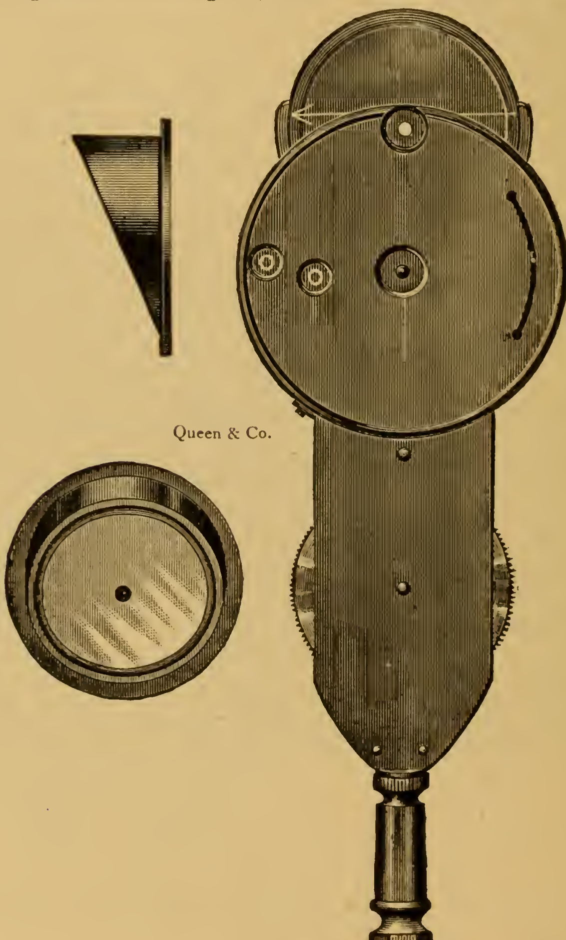


Fig. 87.

towards the light, and if you use a lens back of it, you have to look through it obliquely. This not only increases the strength of the lens, but produces an astigmatic effect.

Dr. Fox's ophthalmoscope (Fig. 87) is a modification of Loring's. The advantage claimed for it over Loring's is that it has a drive-wheel attached to the lower part of the instrument, which enables one to shift the lenses without removing the instrument from its position and without touching the face of the patient.

With the ophthalmoscope one should learn to view the fundus with or without a mydriatic, and the first thing for a beginner is to familiarize himself with the normal condition of the fundus and with its variations before attempting to measure the amount of ametropia or examine for diseased conditions. To see the fundus with its details, it is necessary to follow out a fixed, settled plan, and frequently it requires considerable time to be able to get a satisfactory view. One of the principal annoyances of the beginner is the bright spots or the reflex images from the dioptric media. These must be ignored in the examination of the fundus.

With the ophthalmoscope we can quickly and definitively recognize the ametropic eye in its various forms and degrees. In the examination of the eye with the ophthalmoscope for the anomalies of refraction, there are two methods; namely, *direct* and *indirect*.

Direct Method. By the direct method (Fig. 88), we look directly into the eye examined by reflected light from a gas or lamp flame. The light should be placed at one side and back of the patient's head, say four or five inches to the side, and as many to the rear. The light should be on a

level with the pupil. If the right eye is the one examined, the light should be placed to the right and rear of the patient's head; the observer should sit at the side of the patient, not in front,

Fig. 88.

and look with his right eye. An adjustable chair or stool should be used, so as to bring the observer to the same height as the observed. Then, by means of the ophthalmoscope, reflect the light through the pupil into the eye. In this way, if

the media are clear, the whole fundus of the eye can be illuminated, and one looks upon the retina and optic nerve. This is the only place in the whole body where the circulation of the blood is exposed to view.

In order to see the fundus clearly, as in looking through a key-hole into an illuminated room, you have to come close to the pupil, even almost to absolute contact with the face of the person examined; then, by looking through, you get a view of the back part of the eye.

In examining the left eye, the light should be at the left and rear of the patient. The observer should be seated at the left side of the person examined and observe with his left eye (Fig. 88). Beginners, especially, are inclined, as a rule, to examine always with the right eye. This will not do; if you examine the left eye with your right, it brings your face exactly in front of the patient's (*nez à nez*), the breath of each being inhaled by the other, which in many instances would be extremely unpleasant; besides, such a position does not admit of the close proximity in this method necessary to gain distinct outlines of the fundus. Figures 89 and 90 also show the direct method.

By this method the fundus of the eye with its blood-vessels may be seen at some distance away, and by their appearance we are able to ascertain the different conditions of the eye, whether it be emmetropic, myopic, hyperopic, or astigmatic; for instance, if the fundus be viewed at fourteen inches, the light thrown into the eye by means of the ophthalmoscope, the blood-vessels

of the eye under examination, upon the moving of the head of the observer, will seem to travel in a certain direction. In myopia they will appear to travel in an opposite direction from that in which the head of the observer is moved. If it be moved to the right, they will go to the left, and *vice versa*. The latter is always a positive proof of myopia. This is true with the ophthalmoscope having a concave mirror.

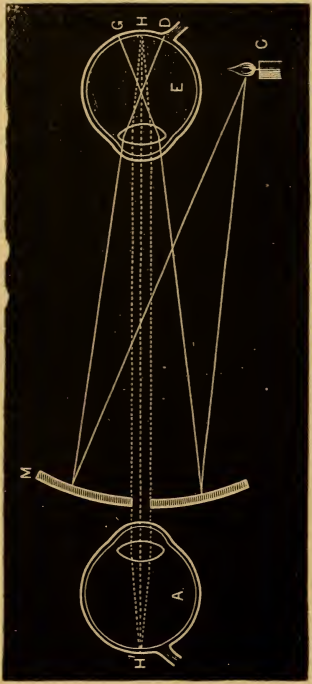


Fig. 89.

In hypermetropia, the reverse is true. Here, the blood-vessels seem to move in the same direction that the head is moved; if the head is moved to the right, they will go to the right, and *vice versa*.

If it is a case of astigmatism, the vessels will be seen more distinctly in a certain meridian than in the opposite one.

In emmetropia, the observer has to approximate the observed eye in order to see the vessels distinctly, and then, as his head is moved, the vessels behave as in hypermetropia.

TO MEASURE THE AMOUNT OF AMETROPIA BY THIS METHOD. The examiner must come near the eye of the patient, say within an inch of his face (Fig. 88). The power of accommodation of the eyes of both the patient and examiner must be thoroughly relaxed. This is easier for the patient than for the examiner, as by the dazzle of the light thrown into the eye the patient intuitively relaxes his accommodation; however, this must not be wholly relied upon, but the patient's attention should be directed to a distant object. It is not so easy for the surgeon to relax his power of accommodation. He is inclined to look at the fundus as from a near point, whereas he should view it as from an infinite distance; for if he looks at it as from a near point with increased convexity of the lens, his eye is temporarily myopic and would require a concave glass to see the details of the fundus clearly.

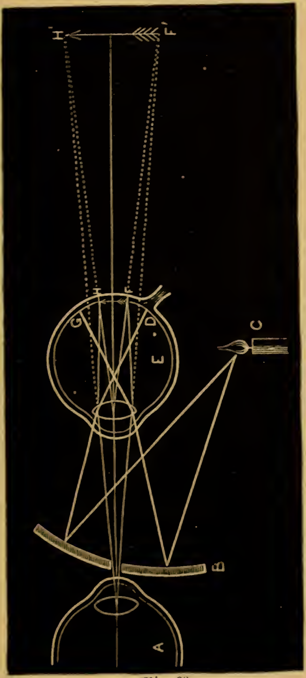


Fig. 90.

Many beginners make this mistake, believing that because a concave glass brings out the details sharper they have a case of myopia to deal with, whereas the opposite condition may obtain.

The optic disc, *i. e.*, the optic nerve, is the first object to look for. Then a little to the temporal side about the same height, the yellow spot, and within the yellow spot a light dot, the *fovea centralis*. The bright red reflex from the retina, illumined by its light pink disc, from the center of which the arteria centralis retinæ and accompanying veins radiate, the macula lutea with the fovea centralis, and the rich, mottled, granular appearance of the retina give a most beautiful picture. (Plate VI.)

If the eye is a normal, emmetropic eye, the retina will present a bright, rose-red, granular appearance, with a circular disc at the nasal side of its center; and about six mm. to the temporal side of this, just at the center of the fundus, at the same height, will be seen a deep, reddened, or slightly orange shaded spot, the macula lutea, in the center of which is a light spot, the fovea centralis.

The *arteria centralis retinæ*, or central artery of the retina, has two main branches, one ascending and the other descending, both of which immediately give off numerous branches that radiate over the surface of and permeate the retina. The accompanying veins converge from the retina to the temporal side of the center of the disc, and, as a rule, pass over the arteries.

This is the usual order; sometimes it is reversed; occasionally, the arteries and veins will be

PLATE VI.

twisted one around the other, and present a sort of a corkscrew appearance. Not infrequently will be observed a pulsation of the veins near the center of the disc; and also at this point the disc may be cupped; that is, appear deeper, giving sometimes the illusive impression of arterial pulsation or glaucoma. Sometimes there is to be seen a slight crescent at the margin of the disc, usually at the nasal side, or, if not a crescent, occasionally a dark line of pigment may be seen, or small flecks or spots of pigment, both of which may be in a physiologically normal eye, not indicating a pathological condition. The arteries are lighter in color than the veins, and have a light streak through their center. More or less choroidal blood-vessels may be seen through the retina, especially in a dark-complexioned person, and the entire fundus presents a darker shade.

In negroes, the contrast between the retina and the optic nerve gives the disc almost a white or slate-colored appearance, which might be mistaken for atrophy of the optic nerve; mulattoes have a rose-tint disc with a dark setting of the retina.

If the eye observed by this close approximation be myopic, the fundus with its details will not be distinctly seen, and the disc will appear larger than the normal, the increase in size varying with the degree of myopia. As a rule, there will be seen a white crescent at the temporal side, varying in size. This crescent differs from the normal and denotes a pathological condition. The crescent is due to the thinning and giving way of the choroid and the retina, allowing the white sclera to

gleam through. This is one of the evidences of posterior staphyloma, or bulging of the eye backwards, and it always impairs vision, varying in degree from a slight amount to nearly total destruction. If the staphyloma is slight and stationary, especially in grown people, little is to be feared; but not so in the young, especially if it is progressing.

In order to see the details of the myopic fundus distinctly, a concave glass must be placed in front of the eye, back of the mirror. In Loring's and similar ophthalmoscopes, as above described, there is a series of small lenses, concave and convex, which can be rotated in front of the eye. The weakest concave lens that will bring the blood-vessels and other details of the fundus distinctly into view will indicate the amount of myopia and the glass to be prescribed in the form of spectacles.

To see the hyperopic eye, unless it be of a high degree, it is not necessary to use a convex glass; but if it be of a high degree, then a plus glass is necessary in order to see the vessels distinctly, and the strongest convex glass with which one can see the smallest vessels distinctly indicates the amount of hypermetropia.

The part to be selected for the examination should be the margin of the disc at its temporal side, looking at the small vessels as they pass over the edge of the disc. This is a delicate test, as it requires but a fraction of a D. to throw these blood-vessels at this point in or out of focus. Some surgeons prefer to examine the smaller vessels near the macula lutea instead of those at the margin of the disc, because the macula is at the posterior

pole of the visual axis. In making this test it is absolutely necessary that all accommodation be put at rest and that the eye of the observer be emmetropic. If not emmetropic by nature, it must be rendered so by a correcting glass, or allowance must be made for the ametropia.

Fig. 91.

In case of astigmatism, by the direct method, the disc, instead of being round, appears oval and its longer diameter may lie in any of the meridians.

Indirect Method. By the indirect method we view the eye with the ophthalmoscope from a dis-

tance of twelve or sixteen inches, and use an intervening convex lens of two or two and a half

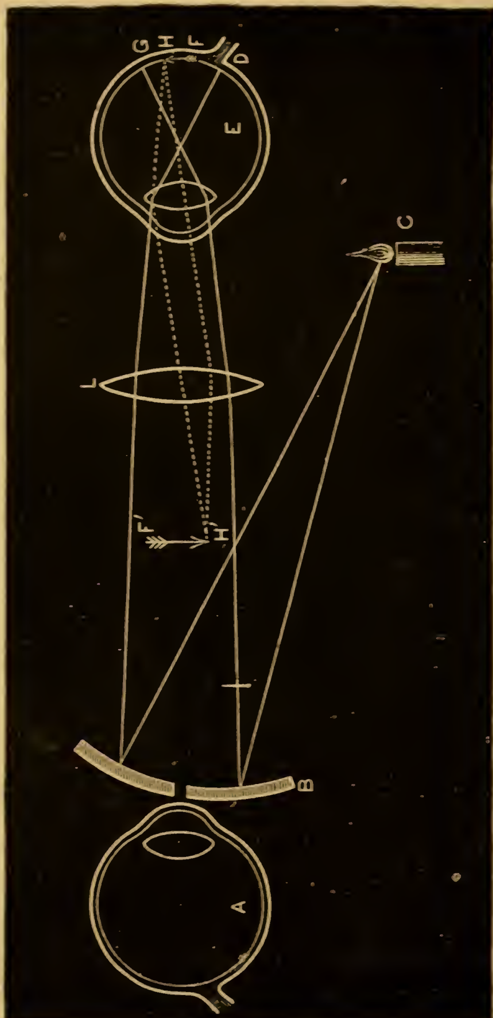


Fig. 92.

in. focal length (20 or 16 D.), placed at its focal distance from the eye (Fig. 91). In this examination the lens is held by the thumb and index

finger directly in front of the pupil, and steadied by the little finger resting on the temple or brow of the patient. By this means an inverted image is seen in the air in front of the lens, which appears smaller and is sharper than by the direct method, especially with a weak convex glass of one to two D. within the ophthalmoscope. In using this test, the observer must bear in mind that the disc and all the details of the fundus are inverted and appear smaller.

In using the indirect method, the size of the field depends upon the strength and size of the objective glass. If the pupil is dilated and a lens of plus 13 D. used, the diameter of the field will be about eight millimeters, or four times the area seen by the direct method. Fig. 92 illustrates the manner of making this examination. The lens L is the magnifying intervening lens producing an aerial image at F′H′.

The inverted image of the disc produced by a convex lens at a certain fixed distance from the cornea is larger in hyperopia and smaller in myopia than in emmetropia. If the lens that is held in front of the eye is gradually withdrawn, the aerial image of the disc enlarges or diminishes according to the form of ametropia (myopia or hyperopia). If it does not change in size, it is a case of emmetropia, as the rays issuing from such an eye are parallel and the image formed by the object glass will always be situated at its principal focus. If diminution takes place as the lens is withdrawn, it is a case of hyperopia, and the higher the hyperopia the greater is the diminution.

If the image is larger as the lens is withdrawn, the case is one of myopia. In astigmatism, as by the direct method, the disc, instead of appearing round, is oval, and if one meridian decreases while the other remains stationary as the lens is withdrawn, it is a case of simple hyperopic astigmatism. If the whole disc decreases in size, but one meridian diminishes more than another, it is a case of compound hyperopic astigmatism. An increase in one meridian, the other remaining stationary, indicates simple myopic astigmatism. An increase in the disc, but in one meridian more than in the other, indicates compound myopic astigmatism. If one meridian increases while the other decreases, the case is mixed astigmatism.

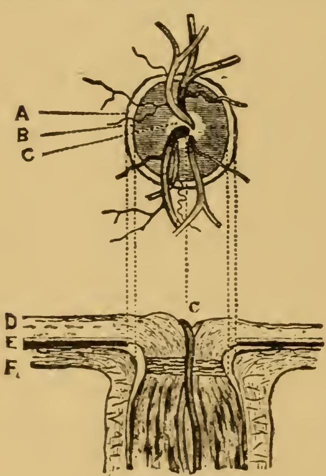


Fig. 93.

The direct method has this advantage over the indirect, in that the parts all come out in their true position and the image is magnified several diameters.

The indirect method has also its advantages. It gives a larger field, and by this method we are able to make a more rapid examination of the whole fundus. The direct method gives a smaller field, but greatly magnified, and any slight abnormality, change, or defect of the fundus will be detected by this method, whereas it might be overlooked by the indirect.

The blood-vessels of the emmetropic eye should

be easily seen without the aid of a lens, especially at a near point to the eye.

Appearance of the Fundus by the Direct Method. In people of dark complexion the fundus of the eye has a slightly granular appearance, while in those of light complexion the fundus shows its choroidal vessels with lighter-colored interspaces. People with neither very light nor dark complexion have a fundus in which the choroidal vessels appear large with dark-colored interspaces.

The *macula lutea* is about six mm. from the center of the optic disc and is darker in color, having a light spot in the center, the *fovea centralis.*

The *optic nerve* (Fig. 93) is from one and one-half to two mm. in diameter, and is much lighter in color than the surrounding retina. It has a light pink-rose tint. There is usually a slight depression in the center, called the "physiological cup" (C).

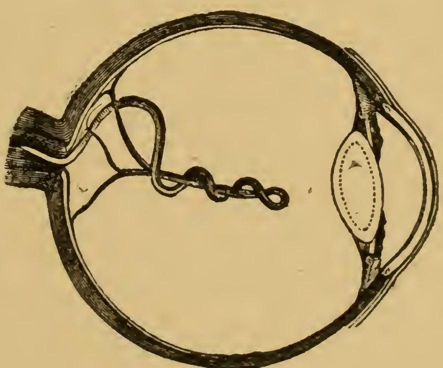


Fig. 94. (Noyes.)

The optic disc has a well-defined margin where the choroid joins the nerve, frequently with some traces of pigment, known as the *choroidal ring* (A).

The *sclerotic ring* (B) is a light circle within the choroidal ring.

Sometimes the hyaloid artery is seen projecting into the vitreous body; occasionally it extends quite up to the posterior surface of the lens, or it may

advance nearly up to the lens and then turn back, coiling about itself and dipping down into the retina (Fig. 94).

Enlargement of the Ophthalmoscopic Images and How to Determine the Amount. The nearest distance at which we can distinctly see an object is from four to five inches from the eye, and when the object is approximated to the eye until it is one or two inches distant, the image is blurred and indistinct; but when we examine an eye with the ophthalmoscope, we can generally get a better view of the fundus by coming almost into contact with the eye examined. The eye being about one inch in diameter, the examined fundus is consequently not much more than an inch distant from the observer's eye, and yet we are able from said distance to obtain a clear and well-defined outline of the fundus and its details, whereas any external object could not be seen with distinctness at such a short distance without the aid of a converging lens; and so it would be impossible to see the fundus of the eye were it not for its refractive media, which act as a bi-convex lens, and magnify the image of the fundus. Hence, it must be borne in mind that when looking into the eye through these media by means of the ophthalmoscope everything seen at the fundus is enlarged at least eight or ten times its real size; but as the fundus is viewed through the refractive media of the eye and all images or objects are seen magnified, we come to look upon them from their apparent size and relation one to the other, rather than from their real size and condition. For instance, instead

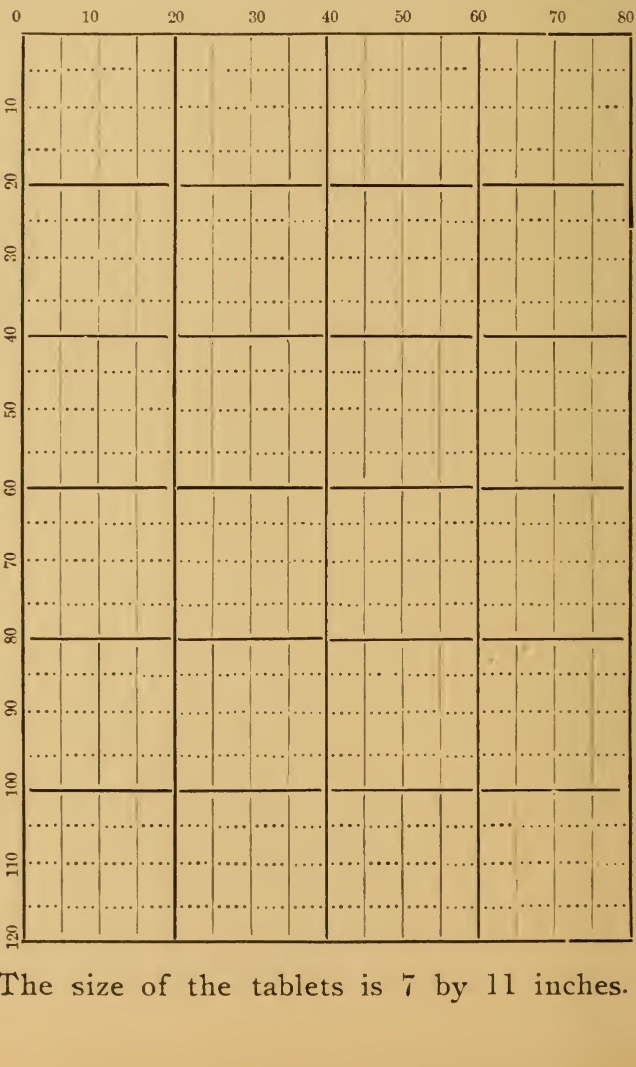
of regarding the optic disc as less than two mm. in diameter, we look upon it as being as large as the ball of the finger, or about eight mm.; and so with the distance of the fovea centralis from the optic disc, instead of about four mm., we think of it as being sixteen or twenty mm. away. The same with any foreign body that may be lodged in the retina; it appears much larger than it really is, and at a greater distance from a given point than its real distance. Therefore, it is of practical importance that we be able to determine at once the real size, or, what amounts to the same thing practically, the magnification. Dr. Landolt has from accurate calculation and experiment demonstrated that the image at the fundus of the eye by the direct method projected thirty centimeters will be magnified just twenty times its real size.

To facilitate the measurement and to make the same a matter of record, I have arranged a tablet which is checked off into squares by parallel lines five mm. apart (page 116). The tablets come in sets of two, one for each eye. They are to be placed just thirty cm. or one foot back and to one side of the plane of the patient's iris, the one for the right eye being placed to the right of the patient, and that for the left to the left of the patient, so that when examining the right eye your left will be in front of one tablet, or if examining the left the other tablet will be opposite your right eye. The tablet may be attached to the wall or to the back of the patient's chair. The center of the tablet should be at the same height as the pupil.

....189....

Name..*age*..................

MAP of the magnified image of the fundus of the eye as seen at a distance of thirty cm.



The size of the tablets is 7 by 11 inches.

To project the picture of the fundus of the right eye, sit at the right side of the patient and view the eye with your right, looking at the tablet with your left. To examine the left eye, sit at the patient's left side and examine with the left eye, looking at the tablet with your right.

At first, it is difficult to project the picture of the fundus and see it on the plaque, but a little practice will soon bring it out. If examining the right eye, ask the patient to look slightly to the left and view from the nasal side; that is, look from within outwards. At first, you will probably see the picture on the cheek or temple of the patient; if then you ask the patient to look slightly more to the left, the picture will shift from the face to the plaque, and at this distance of thirty cm. it will be magnified just twenty times its real size. Thus it is easy to determine at once the size, relation, and distance apart of all parts of the retina. For instance, if the diameter of the optic disc be two mm., the diameter of its projected image on the tablet will be about forty mm., or the length of eight squares, and hence will occupy the circular space of nearly sixty-four small squares, or four large squares.

Again, if the distance from the center of the disc to the center of the macula lutea be six mm., then the distance on the tablet should be 120 mm., or the length of twenty-four small squares.

A tracing with pencil of the details of the fundus as the picture is projected upon the plaque can be readily made, showing both normal and abnormal conditions as to size, position, relation,

etc.; for instance, any foreign body lodged on the retina can be located and its size estimated; scotomata, hæmorrhagic or pigmentary spots mapped out; and then the page can be torn off and filed away in the record book for future reference.

It will be readily seen that this tablet is very useful to the oculist, as it is accurate, easily employed, and a valuable aid to diagnosis. It is also valuable as a record, having, besides the picture of the projected fundus, the name and age of the patient, as well as the date of the examination, space for which is left at the top of each page.

The value of this plan of gaining data is so obvious as to need little more than mere mention, and it is of such practical value as to recommend itself to all painstaking and careful observers.

SHADOW TEST, RETINOSCOPY, KERATOSCOPY, PUPILLOSCOPY, SKIASCOPY. This test, which is very valuable as an auxiliary, is especially useful in the examination of the eyes of children, as well as of those people whose statements are not to be relied upon. It is especially advantageous in the examination of children, as it is difficult to get them to fix an object (in the examination with the ophthalmoscope they invariably want to look at the instrument or at your eye).

In the shadow test, the kind of refraction is determined by the direction of the shadow in the pupil cast by the reflection of light from the retina. The patient should be placed in a darkened room, with a lamp, gas, or electric light immediately above his head. The operator should be at least a meter

away, and with a plane mirror he should reflect the light into the eye (Fig. 95). The pupil should be dilated, with the power of accommodation at rest. With the flat or plane mirror, reflect the light into the eye. This will produce a shadow of the fundus in the pupil; and this shadow is made to change its position by simply tilting the mirror. In the

Fig. 95.

emmetropic, hyperopic, or very slightly myopic eye, the shadow will flit across the pupillary area in the same direction that the mirror is tilted. This shadow appears at the edge of the cornea, and, according to the amount of tilting or rotation of the mirror, advances from the edge over or across the pupil. In the emmetropic eye the shadow is

very dim, and requires but a very weak glass to reverse its direction. In the hyperopic eye the shadow is more distinct. In the myopic eye, if the degree of myopia is less than 0.25 D., the shadow goes in the same direction as in hyperopia and emmetropia. If the degree of myopia is more than 0.50 D., the shadow produced will travel in the opposite direction from the way the mirror is tilted. If the mirror be tilted from above downward, the shadow will creep up from below and pass off at the upper part of the pupil, and *vice versa;* if the mirror be tilted from the temporal to the nasal side, the shadow will creep over from the nasal to the temporal, and *vice versa.*

With the plane mirror the method is more simple than with the concave (the one ordinarily used with the ophthalmoscope). If the concave be used, we have a reversed condition; *i. e.*, in the emmetropic, hyperopic, or slightly myopic eye, the shadow will travel in an opposite direction from which the mirror is tilted; and in the stronger myopic it will travel in the same direction.

The accompanying figure (Fig. 96), as given by Nettleship, will explain these phenomena.

"With a plane mirror, the source of light for the observed eye is an erect and virtual image of the flame formed at the same distance behind the mirror as the lamp is in front of it. In Fig. 96, 1, this image is at *l*, the virtual focus of L. A second and inverted image of *l* is formed on the retina of an emmetropic eye at I. When the mirror M is rotated to M′, *l* will move in the opposite direction to *l*′, but its retinal image I will

move to I′; that is, in the same direction that the mirror is rotated; or, in other words, it moves

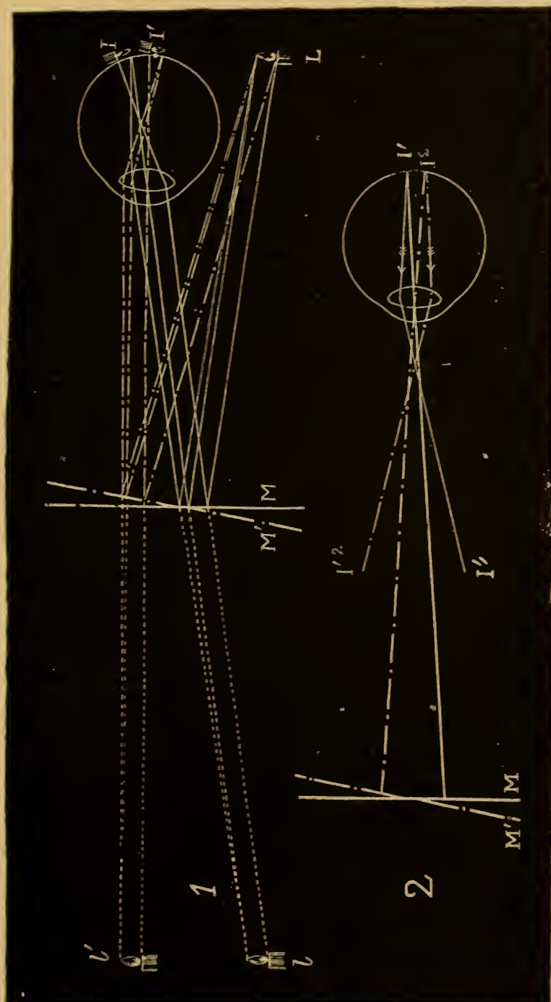


Fig. 96. (Nettleship.)

with the mirror. These movements of *l* and I occur in every eye, whatever its refraction. In emmetropia and in hypermetropia the movement of the

retinal image is seen as it occurs (and therefore is said to move *with the mirror*); but in myopia

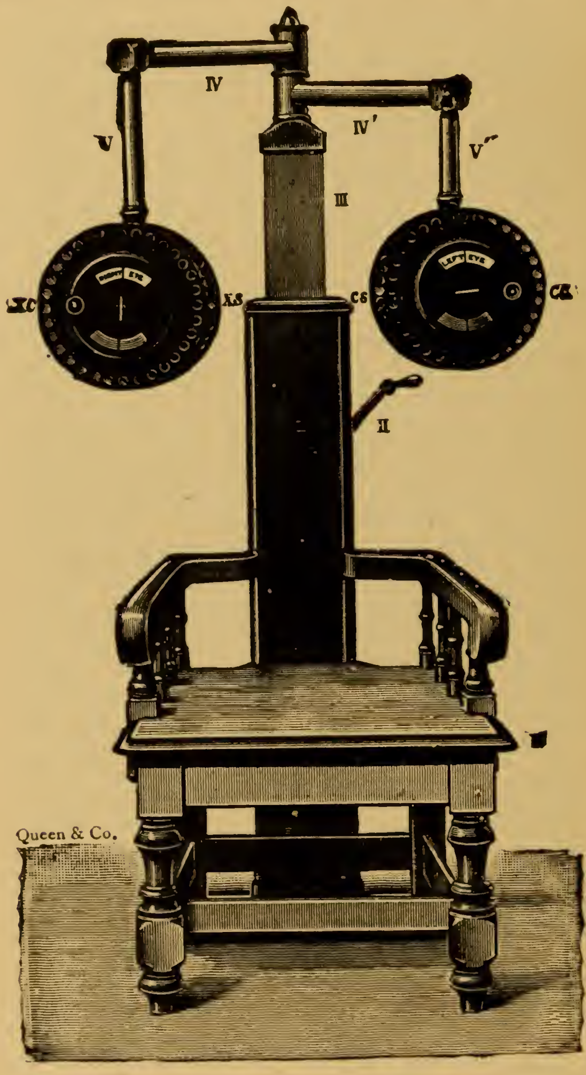


Fig. 97.—Fournet's Refractometer.

(Fig. 96, 2) the observer sees an inverted image of I formed at the far point of emmetropia, and its

movements are exactly the reverse of those of the retinal image; therefore when, on rotating M to M′, I′ moves to I^2, the image I'^1 seen by the ob-

Fig. 98.

server moves to I'^2; that is, *against the mirror.* If the plane mirror be used at a distance of more than one metre, say four feet, from the patient, a movement of the shadow with the mirror will

occur in myopia of 1 D. or less, but if the observer be two metres away, the characteristic movement against the mirror will be obtained, unless the myopia be less than 0.50 D." (Nettleship.)

To ascertain the degree of ametropia, the box of trial glasses with trial frames may be employed. Adjust the trial frame to the patient's face, covering the eye not to be tested, with an opaque disc. If it is a case of myopia, place from the trial box a weak concave glass in front of the eye; then, if on tilting the mirror the shadow still continues to travel in an opposite direction or against the mirror, employ a stronger glass, and so continue until the shadow is dispelled or reversed. If the glass cause the shadow to travel with the mirror, it shows that the myopia has been over-corrected. In hyperopia a convex glass must be used, beginning with a weak one and continuing with stronger ones until the shadow is dispelled. If the shadow is caused to travel against the mirror, it shows that the hyperopia has been over-corrected. The glass that will dispel the shadow, or slightly turn it with the mirror, will indicate the amount of hyperopia. Different forms of astigmatism can in a similar way be ascertained. Instead of the trial glasses from the box, Fournet's compound ophthalmic refractometer (Figs. 97 and 98) or Bull's optometer (Fig. 99) can be used, one eye being covered by an opaque disc; then rotate before the eye being tested the large disc carrying concave or convex glasses, according to whether it be myopia or hyperopia to be corrected.

CHROMATIC TEST. This test is based upon

chromatic aberration. As has already been noticed, a prism separates white light into the different prismatic colors: red, orange, yellow, green, blue, indigo, and violet. The red is the least deviated from its primitive direction, blue and violet the most. If we take a glass that reflects or transmits only the red and the blue (Fig. 100), excluding all other colors, and view through it a lamp or candle flame at a distance of 16 or 20 feet, the blue rays will be more strongly refracted than the red, and come to a focus sooner than the red ones. The latter will be brought to a focus later on.

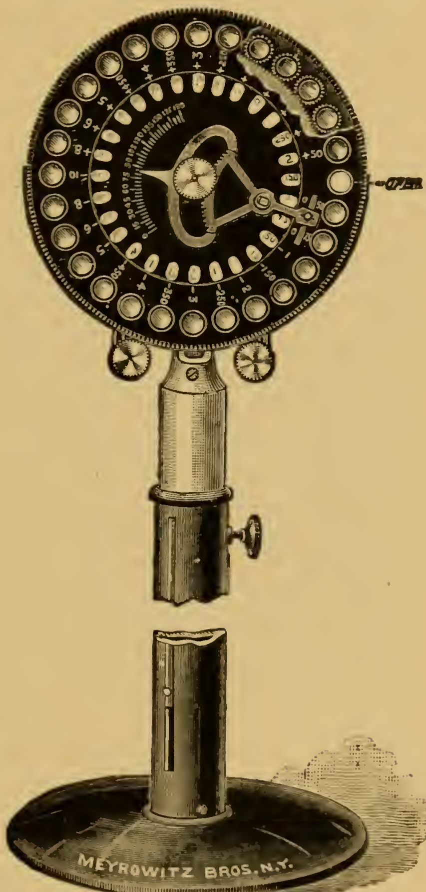


Fig. 99.—Bull's Optometer.

If the eye is emmetropic (*i. e.*, if its retina is at E in Plate VII), each blue ray crosses a red one at the retina; thus the two colors are mingled, and the flame will be seen as a diffuse violet color with a border of a slightly deeper hue.

If the eye is hyperopic (HH, Plate VII), the

blue rays, converging faster than the red, meet the retina within the red, and thus the flame appears with a distinct blue center and a red border.

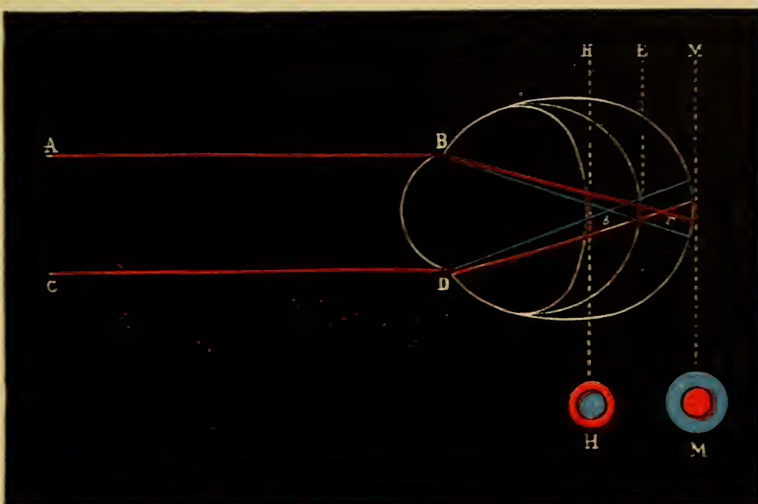
If the eye is myopic (MM, Plate VII), the blue rays cross in front of and meet the retina as divergent outside of the red rays, and thus the flame will appear with a distinct red center and a purple or blue border.

Fig. 100. Chromatic Glass.

Landolt has beautifully illustrated this in his work on "Refraction and Accommodation."

"In Plate VII, let ABCD be a section of a pencil of rays given off from a red-blue point sufficiently distant so that these rays may be regarded as parallel. The focus of the blue rays is at *b;* that of the red ones at *r*. The eye is adjusted to the distance of the luminous point when the circle of diffusion received upon its retina is at its minimum. This is the case when the sentient layer of the retina lies between the two foci (E, Plate VII). In this case the point will appear as a small violet circle composed of the two colors. If the retina be in front of this point at the focus of the blue rays, the eye will perceive a blue point surrounded by a red circle, the latter being formed by the periphery of the luminous cone of red rays which come to a focus only after having passed the retina. The blue point will become a circle of diffusion larger in proportion as the retina is nearer the dioptric system, or as the focus of the

PLATE VII.



rays is further behind it, but the blue circle will always be surrounded by a red ring (H, Plate VII). If, on the contrary, the retina is behind the focus of the red, the blue will be greater in diameter than the red, and we shall have a red circle of diffusion, larger in proportion as the retina is further from the focus, but always surrounded by a blue ring (M, Plate VII). If the red-blue point is five or more metres distant, the emmetropic eye will see it more distinctly as a small violet point. The hyperopic eye, whose retina is in front of its focus, will see a blue circle surrounded by red. The myopic eye, whose retina is behind its focus, will see a red circle surrounded by blue. The size of the circles will be in direct proportion to the amount of ametropia." —*Landolt.*

To determine the degree of ametropia by this test, use a glass that will correct the chromatic aberration, and this glass will indicate the degree of ametropia. If it be a case of myopia, use the concave glass that will dispel the blue fringe, converting it into a slightly red tint with a violet center. If it be a case of hypermetropia, use the convex glass that will diffuse these colors and produce a violet red. This is a delicate test, and may be used in doubtful cases as corroborative.

Scheiner's Method of Optometry. Take a card with two small perforations and place it in front of the eye to be examined. The perforations must be so near together that rays passing through them will enter the pupil. The patient is directed to look at a flame through the card six metres, or twenty feet, away. Rays emanate from the flame

in all directions; some fall on this diaphragm; a greater number, however, are cut off, and only a few pass through the two openings; and if the eye be adapted to the flame (*i. e.*, if it be emmetropic), these two sets of rays will meet exactly on the retina, forming there one image of the flame (B, Fig. 101).

If the eye be hyperopic (the accommodation put at rest), the two sets of rays will reach the retina before meeting, each set forming an image of the flame (A, Fig. 101). The greater the hypermetropia, the further apart will be the images. These are projected outwards as crossed, and the

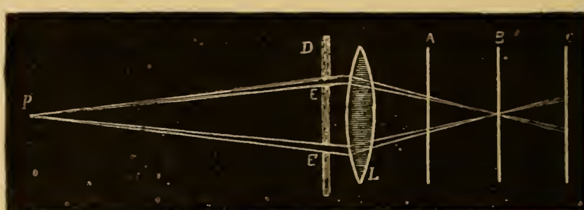


Fig. 101.

patient sees two images of the flame. The convex glass which, placed behind the card, causes the flame to be seen singly is the measure of the hypermetropia. If the eye be myopic, the two sets of rays cross before striking the retina, reach it as divergent, and two images are formed (C, Fig. 101). These images are crossed again as they are projected outwards, and, having twice crossed, *homonymous* images result. To determine the amount of myopia, find the concave glass which, placed behind the diaphragm, will bring the two images into one. Suppose the card to be horizontal before the eye, and a red glass placed in front of one of the open-

ings, say the right; then, if only one flame is seen, the case is emmetropia. If two images of the flame appear, one white and the other red, the red to the left, it is a case of hyperopia. If the red appear on the right, the case is myopia. The further apart the images are, the greater is the ametropia.

The test by the trial case, the first mentioned in this chapter, is the crucial test. This test and the examination by the ophthalmoscope are to be relied upon, while the others may be used more as corroborative, and in ordinary cases may be altogether dispensed with.

Optometry by the Perimeter. This is the method used in determining the field of vision and its limitations. The field of vision is the space bounded by a line including all objects perceptible to the eye without change of fixation. For instance, when we look at a particular object, although the eye is fixed upon it, other objects at either side, above, or below within a certain limit are also perceived; the further they are outside of the point of fixation, the more are they indistinct, for the further are their images from the macula lutea, which is the most sensitive part of the retina; and the sensitiveness of the retina gradually diminishes from this part. The nose, eyebrows, and cheek limit the field of vision.

At the temporal side the limit is 90°, at the nasal it is 50°, above it is 50°, below it is 65°.

The perimeter (Fig. 102) is an arc, usually half a sphere mounted on a base and suspended on a pivot, so as to be rotated through all meridians. It is spaced into degrees from 0 to 90 in both directions.

At the foot of the instrument is attached an upright rest for the chin of the patient. The standard is about twelve inches from the center of the arc. The chin of the patient resting on the standard, the eye should be on a line with the center of the arc, at which point is a bright white spot. The eye under examination is to be directed

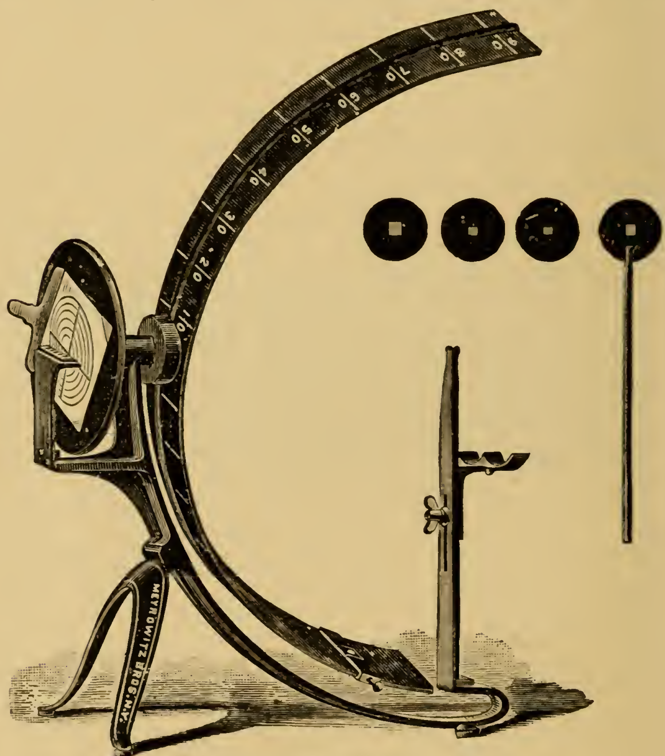


Fig. 102.

to the white spot, the other eye being covered. My custom is to turn the arc into the vertical position, and then pass the movable white disc along the arc from zero toward the circumference, until it passes out of view, indicating the same on the chart. I then rotate the arc into another merid-

ian, say 15° to the left, proceeding as before, until I have entirely gone around to the point started from. The perimeter is not only useful for ascertaining the field of vision, but also for mapping any defects, such as blind spots (scotomata). The patient may tell you as you move the white disc along the arc that at certain points it disappears, but comes again into view as you continue to move it further on. For instance, it may pass out of view at 10°, coming in again at 20°. It may again disappear at 40° and reappear at 50°. Between 10° and 20°, and 40° and 50°, in the case supposed, there are blind spots. Then, by shifting the arc into another meridian, we may find that the space where the spot appears is shorter or longer as the case may be; thus we map out the extent of the blind spot, or scotoma. This is of great practical value in certain diseases of the retina and choroid. If examinations are made from time to time and the results recorded, it is easy to determine if the disease is stationary or progressive. It is also a means of determining the amount of strabismus. (See chapter on Strabismus.)

CHAPTER VII.

MYOPIA.

Myopia, brachymetropia, or near-sightedness, is that condition of the eye in which the refractive power is too great, or the antero-posterior axis of the eyeball is too long, the eye thus having its focal point for parallel rays in front of the retina; in other words, it is adjusted for near objects only, whose rays meet the eye as divergent. Therefore, to focus the rays of light from a distant object (or parallel rays) a concave glass is required to diverge these rays that their focus may be further back, or on the retina. (Fig. 103, *dotted lines.*)

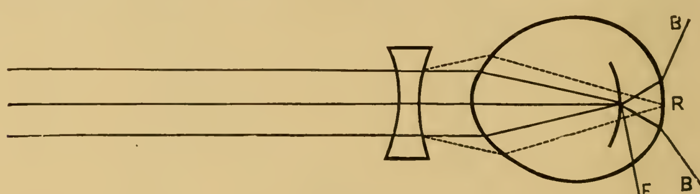


Fig. 103.

The concave glass that enables the myope to see No. 20 of Snellen's test type at twenty feet would indicate the degree of myopia. However, many myopic eyes are non-amenable, or only partially amenable, to improvement by glasses, because of some other affection, as posterior staphyloma, disease of the vitreous, choroiditis, etc.

The accompanying table taken from Donders

shows the increase of the length of the eyeball compared with the degree of myopia:

Degree of Myopia.	Amount of Length'ing.	Total length of Axis.	Degree of Myopia.	Amount of Length'ing	Total length of Axis.
D.	mm.	mm.	D.	mm.	mm.
0.0	0.00	22.824 (Normal.)	8.0	2.93	25.75
0.5	0.16	22.98	8.5	3.14	25.96
1.0	0.32	23.14	9.0	3.35	26.17
1.5	0.49	23.31	9.5	3.58	26.40
2.0	0.66	23.48	10.0	3.80	26.62
2.5	0.83	23.65	10.5	4.03	26.85
3.0	1.01	23.83	11.0	4.26	27.08
3.5	1.19	24.01	12.0	4.73	27.55
4.0	1.37	24.19	13.0	5.23	28.05
4.5	1.55	24.37	14.0	5.74	28.56
5.0	1.74	24.56	15.0	6.28	29.10
5.5	1.93	24.75	16.0	6.83	29.65
6.0	2.13	24.95	17.0	7.41	30.23
6.5	2.32	25.14	18.0	8.03	30.85
7.0	2.52	25.34	19.0	8.65	31.47
7.5	2.73	25.55	20.0	9.31	32.13

All myopic eyes to a certain extent are diseased eyes. If there is a greater degree of myopia than six dioptrics, perfect vision is not usually obtained by glasses.

CAUSE.

Heredity is frequently responsible for myopia. Myopia may increase in degree in each successive generation. The most frequent cause is abnormal increase in the length of the eyeball in its antero-posterior axis. This takes place after birth; and, though the child may be hyperopic at birth, there is a predisposition to myopia later in life. This extension occurs chiefly at the posterior portion of the globe, and may develop into posterior staphyloma (bulging backward), which is accompanied,

with rare exceptions, by thinning and atrophy of the choroid and sclera, and frequently with detachment of the retina. Convergence in the act of accommodation may induce myopia, especially in the young when the eye is plastic. At birth, the the eye is hyperopic; later on, it may become emmetropic or myopic.

These eyes should always be examined with the ophthalmoscope in order to ascertain whether the condition of the optic nerve and retina be normal, or whether they are hyperæmic and congested; and they should also be examined for posterior staphyloma.

We have seen from the anatomical structures of the ciliary region that the ciliary muscle and ciliary processes, as well as the ora serrata, the ligamentum pectinatum iridis, and the choroid are all intimately connected (Plate IV). In the exercise of the power of accommodation there is more or less strain on the choroid, and, in fact, upon the whole uveal tract; and if this power be overtaxed, as is frequently the case with school-children and those who are compelled to use their eyes continuously for near objects, affections of this part of the eye, such as choroiditis and cyclitis, are liable to follow. It is a well-known fact that choroiditis is a frequent forerunner of myopia with posterior staphyloma or sclero-choroiditis posticus. The eye continuously employed for near objects for too long a time is liable to spasm of accommodation. We know that the eye when adjusted for near objects is temporarily myopic; that is, it is adjusted for divergent rays. In spasm of accommodation the

eye fails to relax and readjust itself for distant objects and therefore remains permanently fixed for near objects; or, in other words, is myopic. Continued tension, then, of the accommodation for near objects is a cause of myopia. This accounts for its greater frequency among the higher and literary classes than among the illiterate.

The production and increase of myopia by continuous use of the eyes at near objects, as reading, writing, sewing, engraving, watchmaking, etc., appear to find their explanation chiefly in the fact that the inner tunics of the eyeball become congested, and finally inflammation and giving way of these membranes ensue The near approach of the object necessitates a strong convergence of the optic axes; this gives rise to a strain of the muscles and tunics of the eye. The stooping position generally indulged in during such employment will also produce congestion by inviting an accumulation of blood to the inner tunics, which may finally result in inflammation. This congestion or augmentation in pressure, if long continued, necessarily leads to an extension of the tunics at the posterior pole, and so induces posterior staphyloma.

A clouded cornea or an opaque lens may cause myopia from the patient's bringing the objects nearer to the eye in order to obtain larger and more distinct retinal images. The degree of myopia is often increased during childhood by long-continued study; also by insufficient illumination and a faulty construction of the tables or desks at which the pupils read or write.

Referring to the report gathered from the ex-

amination of 2040 school children (see appendix), we find that in one school the largest per cent of defective eyes was found in the lower grades, where the first and second year pupils (for want of adequate accommodation) were crowded into a room calculated for older pupils, and hence the distance between the desk and the seat was too great, as well as that from the seat to the floor, compelling the little pupil to hang, as it were, upon the desk, his feet not touching the floor. This position, of necessity, brought his face too near the book or slate, and hence taxed the power of accommodation of the eye to a great degree, which resulted in spasm of accommodation—a forerunner of myopia.

An insufficient illumination necessitates a close approximation of the object, which gives rise to a strain of the accommodation and congestion of the eyes—another cause of spasm of the ciliary muscle.

Myopia is found in a larger per cent among the German people than in those of other nationalities. The style of type probably has something to do with this, as it requires a greater effort to see the German text than the Latin text. It is still a query whether tobacco may be regarded as an etiological factor of myopia. Small print, long lines, or a narrow space between the lines lie in the same category of criminal factors of myopia. Germans are now using the Latin text, and myopia is gradually diminishing among them.

The myope is more reticent, is less inclined to engage in out-of-door sports, and occupies his mind in literary pursuits. From the very fact that he is shut out largely from the subtle beauties of

nature and the ordinary out-of-door sports, he betakes himself to his friends—his books. His eyes, therefore, are more constantly subjected to the strain of convergence and accommodation in looking at small and near objects.

It was formerly supposed that increased convexity of the cornea was the cause of myopia, but this is erroneous, for Donders has found that the cornea is, as a rule, less convex in myopic persons than in the emmetropic. Increase of the curvature of the cornea (as in conical cornea) may, however, provoke or be concurrent with myopia.

SYMPTOMS.

Distant objects do not present a clear and well-defined outline, but appear irregular, enlarged, and surrounded by a halo. In order, therefore, to improve the vision for distant objects, persons often acquire the habit of nipping the lids together. This, first, narrows the opening between the lids (palpebral aperture), cuts off some of the peripheral rays of light, and diminishes the circles of diffusion on the retina; thus, the object gains in distinctness of outline.

Second, a certain amount of pressure is exercised upon the eyeball, the cornea rendered somewhat flatter, and the refraction thus slightly diminished.

The myopic eye, as a rule, is a large, full eye and is prominent. Compared with the hyperopic eye, the cornea is larger. The myopic eye is clearer and has not so much ciliary hyperæmia as is often seen in the hyperopic eye, due to the fact that the

latter is always exercising its accommodation, thus giving rise to this ciliary congestion. If the lids are separated, it will be seen that the curvature of the equator of the myopic eye is less abrupt than that of the hyperopic eye.

PATHOLOGY.

In considering the pathology of myopia we might mention, besides the affections of the choroid and of the retina with posterior staphyloma, *metamorphopsia*, or derangement of the cones in the macula, which causes an irregular or curved appearance, straight lines or pins appearing wavy or crooked; and widening or crowding together of the rods, with other displacements, giving the effect of magnifying, reducing, or warping the image of the object. Letters are uneven and some stand higher than their neighbors. Sometimes the patient will speak of a certain part of the object looked at as on a higher plane than the other parts, or of the object having a wavy appearance. I remember especially one patient who complained of these symptoms, who had received a blow upon the eye without reducing the vision very much; she was greatly disturbed by this metamorphopsia. This derangement is due to exudation or infiltration of matter into the retina, disarranging the rods and cones.

Megalopsia. Sometimes, objects appear larger than they really are. This condition is called *megalopsia.* It is due to the crowding of the elements of the retina together, the image embracing more of the rods and cones than normally.

Micropsia. This is a condition where the ob-

ject appears smaller than it really is, and is due to a spreading or separation of the rods and cones, the image embracing less of them than normally.

DIAGNOSIS.

The diagnosis is generally easy. Distant objects cannot be clearly distinguished and a suitable concave glass may render them distinct. However, a person may hold small objects very close to the eye, or not be able to see well at a distance, and yet not be myopic, but hyperopic, and require a convex glass instead of concave.

Myopia may be confounded with amblyopia—weak sight. Weak-sighted persons bring small objects very close to the eye in order to gain magnified images. Concave glasses do not enable them to see better or further off; on the contrary, they see worse with them. If a concave glass of the strength of two or more dioptres improves vision, myopia exists; but improvement with a weaker concave glass does not necessarily signify myopia, as a hyperopic eye with spasm is often improved by a weak concave glass. In contradistinction to myopia, a convex glass, no matter how weak, which improves the sight for distant objects, signifies hypermetropia. In examining the eye the test may be objective or subjective. (For the various tests for myopia, see Chapter VI.)

PROGNOSIS.

If the myopia be stationary and there be no staphyloma, especially in the young, there is virtually nothing to be feared; but such is not the case in the adult or in persons further

advanced in life, especially if the myopia be increasing. There is great danger of the staphyloma progressing to final destruction of vision. Myopia exceeding 6 D. should be looked upon as serious; it is called *malignant myopia*. That of less than 3 D. is called *simple myopia*, and in the adult is usually stationary. That between 3 D. and 6 D. is *medium myopia*, and is liable to progress. In a high degree, the younger the subject the greater is the danger, as the disease is very liable to increase. Later on in life, extensive staphyloma and disease of the choroid and of other parts of the fundus are liable to follow. If there be a large crescent with perhaps pigmentary patches and the vision be less than 6 D., the prognosis is grave.

In such myopic people the eye should be carefully examined by the oculist; the field of vision and any existing scotomata should be carefully mapped out by the perimeter (Fig. 102, page 130), and the vision taken; all of which should be made a matter of record. These examinations should be made from time to time to see whether there is any increase in the myopia, staphyloma, or scotomata. If so, the progress may be checked or arrested by changing the habits and occupation of the patient. Out-of-door life should be encouraged, and the employment of the eyes for near and small objects discouraged.

Now, in regard to the myope becoming in process of time an emmetrope, let me say that while static refraction diminishes after a certain age, rendering an emmetrope a hyperope, it is only when

the degree of myopia is very slight that this eye becomes emmetropic.

This diminution of static refraction commences at the age of fifty, and at eighty amounts to 2.5 D., so only the myope of not more than 2.5 D. can become emmetropic even at the age of eighty. A myope with less than 1.5 D. may become hyperopic. Occasionally, people with an excessive degree of myopia, scarcely able to see a foot away, become emmetropic or even hyperopic. But this is only for a very short time, and is always a sad premonition; for while a new world with its minutiæ and glow is for a little while opened to them, everlasting darkness is soon to follow. By the detachment of the retina and its falling forward, the eye temporarily becomes perhaps emmetropic; but soon the retina, thus detached, loses its vitality, and blindness is the consequence.

SEQUELÆ.

In a high degree of myopia, especially in the young, sooner or later complications arise which are due directly to the condition of the myopic eye. Posterior staphyloma is one of the most serious and most frequent sequelæ of myopia. The extension of the eyeball backward causes a thinning of the different tunics, and sooner or later the retina and choroid give way, and a crescent varying in size and extent is to be seen at the disc. Frequently, the whole retina is detached, resulting in total blindness. Retinal hæmorrhage and hæmorrhage between the retina and choroid are often associated with or dependent upon myopia.

The following case illustrates one of the many dire consequences of this anomaly:

CASE. The patient was a man, a farmer, aged thirty years, who became suddenly blind after loading a car with baled hay on a hot June day. After he entered his wagon to return home, he found himself suddenly blind of both eyes. Examination revealed hæmorrhage of the macula with a detachment of the retina, and although the hæmorrhage was absorbed and the retina reattached itself for a time, other hæmorrhages followed, and in the course of a few years he became totally blind. This patient had only a moderately high degree of myopia. This is one of the many sad cases that come under our observation.

A high degree of myopia existing in childhood is almost sure in later life to end in serious impairment if not in total destruction of vision. Many highly myopic eyes become sooner or later cataractous, but the cataract develops very slowly. Frequently the vitreous becomes diseased—partially fluid—and not infrequently is there luxation of the lens. The vitreous loses its consistency and shrinks, and thus favors detachment of the retina and intraocular hæmorrhage.

The myopic eye is far more prone to atrophy of the optic nerve than the emmetropic or even the hyperopic eye. The myopic person is almost invariably annoyed by what is termed *muscæ volitantes*, and what would be physiological in an emmetropic eye is frequently pathological in the myopic eye; the "floaters" of the vitreous become more numerous and opaque, thus obscuring vision.

The myopic eye is more frequently attacked by hyalitis and choroiditis than the emmetropic; hence, the importance of great care not to overtax or abuse this eye. It should be carefully watched, and any complications arising should receive timely and skillful treatment.

TREATMENT.

PROPHYLACTIC TREATMENT. Myopia, which reduces the capacity for enjoyment of the beautiful outer world so greatly, can with knowledge and judicious care be greatly controlled in its development. No child is born myopic. The trouble usually develops in early life, while yet the eye is comparatively plastic. Close work, viewing small objects for a continued length of time or with great frequency, is liable to strain the power of accommodation, producing hyperæmia and congestion of the fundus. This may induce a yielding of the tissues, causing prolongation or staphyloma of the globe.

In view of this, thoughtful people will readily see the importance of giving the young child objects of considerable size, of easy sight, for his playthings. Small ones, necessitating an effort of accommodation to see them, should by no means be given, neither should the games be such as to require short vision. Give the child wide range of out-of-door plays, requiring only distant vision, or let the objects be sufficiently large that they may be easily seen without the effort of accommodation.

When the child is in school he should not be allowed to use his eyes for near work long at any one time. The habit of some teachers, conscien-

tiously ignorant though they may be, of requiring pupils to keep their eyes fixed upon their books through the study hours, under pain of committing a misdemeanor if they once take them off, is pernicious in the extreme. Treat any other member of the body thus—the arm, for instance—hold it out in any one position for a few minutes, a much less time than a study hour, and you will soon realize what it means to violate the great law of nature. Such constant strain of the accommodation will, if persisted in, almost inevitably result in myopia.

That the eye may perfectly develop, it should have frequent change of its range of vision—near to distant, distant to near. Frequent interruption of any kind of work is essential to symmetrical development and the maintenance of a healthy condition of the visual organ; especially is this true with the young.

A child predisposed to myopia should be kept out of the school-room until he is at least ten years of age. Open-air sports should be encouraged, and the child should be occupied with large and distant objects rather than with small and near ones. Gymnastic exercises, and, in fact, any and all means of development of the general system, should be prescribed. The deleterious effects of all stimulants, and especially of narcotics, should be thoroughly impressed upon the mind of the youth.

Those predisposed to myopia should not be allowed to use the eyes for near objects for any great length of time. Two or three hours a day should be the maximum for study.

Print is another matter that must be carefully looked to. Defective, blurred print should never be read—very fine print should also be banished, from school-books especially.

The Latin type is by far the best. The height of letters should not be less than 1.5 mm., and the distance between each word should not be less than 5 mm. The interlinear distance should be at least 3 mm., and the length of a line should not exceed 100 mm. This subject of type, character, size, etc., is of vast importance. The letters should be clear, sharp, and of good size. German type should not be employed in text-books. Pica or great primer is the size that seems best in ordinary use for text-books. We Americans realize the vast difference between our Latin type printed books and that which the Germans until recently were obliged to read in all their literature.

I doubt not this German type is twin sister with the studious habits of the German nation in causing their *enormous* percentage of myopes.

Children under ten years should not be required to study more than two and one-half to three hours a day; those over ten and under sixteen, three and one-half or four hours; and those over sixteen may be allowed to have longer time, but not more than six hours a day. No child should enter the school under seven years of age. Young pupils should be allowed to rest their eyes occasionally by glancing from their books to more distant objects, thereby relaxing the power of accommodation.

Myopia is never congenital, although it may

appear soon after birth; it may, however, be hereditary. It is frequently caused by overuse or abuse by holding the book or work too near the eyes. Long-continued use of the eyes in reading small print, the stooping posture, bad or insufficient light, or a glare of light, any one or all of these combined have a tendency to cause myopia.

In bookkeeping, where there is a necessity for fixing the vision intently, as in casting up long rows of figures, the power of accommodation is on a stretch for a long time. This is especially provocative of spasm of accommodation, which may finally lead to myopia.

The light should be ample; it should not be reflected light, and should never come from in front; but from the side, behind, or above. Preferably it should come from the side, as light coming from above or behind the pupil is liable to cast a shadow upon the book or work. Light in the school-room should come mainly from the north, although a due amount of sunlight should be admitted to the room. Daylight is the best light, and all work of the student by artificial light should be discouraged. If, however, artificial light must be employed, the electric incandescent seems the best, as it is perhaps the nearest approach to sunlight that we have. The electric arc light is an unsteady light, varying in its brilliancy from dazzling to an insufficient illumination, and is very trying to the eyes. The incandescent light is also dazzling, and should be employed with a shade. The oil lamp with a Rochester burner gives a

steady, clear light, and in some respects is even to be preferred to the electric light.

The space area for admitting daylight to the school-room should equal at least one-fifth of the area of the floor of the room. The light reflected from white walls is very severe upon the eye. Walls should be tinted gray or light blue. A child with progressive myopia, however slight, should be prohibited from reading or using his eyes for near vision; especially should this be emphasized if artificial light is used.

To go further back in the prevention of myopia, as well as other evils, we might profit by the wise saying laid down in the laws of Moses, that the evils and indiscretions of the parent are visited upon the progeny, even to the third and fourth generation. It is a well-known fact that consanguinity is responsible for not only anomalies of refraction, but also for diseases of the eye, and of the ear, with total loss of sight and hearing. We have examples every day betraying the sad consequences of the marriage of people of the same blood or of people with these anomalies.

The excessive use of tobacco on the part of the parents, as well as by the student himself, is another well-known cause of affections of the eye.

Of the influence of more favorable appointments of the school-room and a lessened number of hours of work therein upon myopia, I would cite in evidence statistics given by Cohen, who found the percentage of myopia 40. Later investigators, Von Reuse, Seggel, and Reich, all found an increase of the percentage of myopia keeping pace with the

length of time in the schools. Erisman found among scholars occupied

2 hours per day.................17%
3 hours per day.................29%
6 hours per day................40%

The results of my own examination of 2040 pupils in Kansas and Missouri show only 5 per cent of myopia. Had I added the cases of spasm of accommodation which simulates myopia, the percentage would have been much greater. Many of the buildings occupied by these pupils are of late construction, and have generally excellent appointments in regard to seats and hygienic conditions. Where these appointments were most faulty I found the greatest percentage of trouble.

TREATMENT BY GLASSES.

The principal treatment of myopia is glasses for the correction of the anomaly. To ascertain the proper glass, a definite plan must be followed out: first, ascertain the amount of vision. Place the patient at twenty feet from Snellen's test type and test each eye separately. Adjust the trial frame (Fig. 74, page 86) to the patient's face. Test the right eye first, covering the left with an opaque disc. Note how far down the card the person can read the letters. If he can see only number 80 at twenty feet, his vision is but twenty-eightieths. If he is not able to see the largest letter at 20 feet, have him approach the card, asking him to stop as soon as the largest letter comes into view. Note the distance from which he is able to see this letter. If he has to come within 5 feet, his vision is five two-hundredths, since the largest letter should be seen

at 200 feet. Now have him return to his former place at 20 feet from the card, and see what concave glass will improve his vision. Begin with a weak glass, say 1 D. or 2 D., and continue from this to a stronger until the glass is found that gives him the greatest amount of vision. Prescribe always the weakest concave glass that will give the greatest amount of vision. It is always better to under-correct than to over-correct myopia. If too strong a glass be used, it necessitates the exercise of the power of accommodation, which, in the myopic eye, is, from its construction, feeble. If the power of accommodation is brought into requisition by too strong a glass, further complications are liable to be provoked, such as choroiditis, congestion of the retina, and increase of staphyloma. If the myopia be of a high degree, it is advisable to prescribe two pairs of glasses, one for distant and the other for near objects, a stronger glass for the former and a weaker one for the latter.

We have already seen that the myopic eye is adjusted for near objects; for rays of light coming from a near point strike the eye as divergent, and their focus would be at a greater distance back of the principal focus of the eye than that of parallel rays. The myopic eye, having an increased antero-posterior axis, or a high degree of refraction, is already adjusted for divergent rays or those from a near point, and if the object be approximated to the eye, the focus may fall upon the retina without any effort of accommodation, or the aid of a glass, unless it be a very high degree of myopia.

If so, a glass sufficiently strong should be used to increase the divergence of the rays as they enter the eye so that they may have their focus on the retina; it is only in these cases of high degree of myopia that a glass is required for near objects. It is frequently found, however, that people with a considerable amount of myopia are able to use the same

Fig. 104.

glass for near as for distant objects; the glass renders them emmetropic, and so they use the same for near objects by bringing into requisition their power of accommodation, as does the emmetrope. Usually, in low forms of myopia no glass is required for near objects.

In the adjustment of spectacles, care should be taken that the frames properly and accurately fit the face and that the glasses be accurately centered. The distance between the two pupillary centers should be taken, and also the distance from the median line of the nose to the center of each pupil. For this purpose, a pupillometer (Fig. 104) may be used. It is the custom of most oculists and opticians to take merely the pupillary distance, measuring from the center of one pupil to the center of the other. This measurement would suffice in the majority of cases, yet there are exceptions where the nose is not in the median line or the eyes are not symmetrically placed, the distance from the center of the pupil of one eye to the median line of the nose being greater than that of the other.* This should be taken into consideration and each glass accurately centered. The glasses should be on a plane parallel with that of the iris, tilted neither upward nor downward, inward nor outward. If the glasses are not centered and the person looks through the edge, the glass acts as a prism, and of necessity taxes certain muscles; or if the glasses be tilted, they act as cylinders and create an astigmatic effect.

These foregoing facts may be taken advantage of, however, in cases where there is some heterophoria or astigmatism. If it be a case of exophoria

*In case of such an asymmetry, the distance from the median line of the nose to the center of the pupil of each eye should be taken separately. If the pupillometer is used, adjust the indicator to the center of the pupil of one eye, and half the amount registered indicates the distance from the median line of the nose to the pupillary center. The other eye should be examined in the same manner.

with myopia, the concave glass should be decentered outward, that the base of the prism be toward the internal rectus, or muscle to be relieved; also in esophoria with hyperopia, the convex glass should be decentered outward, that the base of the prism be toward the external rectus, or muscle to be relieved. Hyperphoria and cataphoria may be relieved by decentering the concave glass upward or downward, as the case may be. A slight amount of astigmatism can be corrected by tilting the glasses; but it is only in rare cases that this is to be recommended. Care should be taken to select frames of strong and yet as light material as possible. For myopic persons, from obvious reasons, the hook bows are preferable to the straight, or to the nose glasses. The myopic person should be cautioned against bringing the object too near the eye, and also against the stooping posture. He should be instructed to sit erect while reading or working, and keep the book or work as far from the eyes as convenient. Spasm of accommodation simulates myopia, and a mydriatic should be used in all slight forms of myopia or suspected myopia before prescribing glasses.

Many people object to the wearing of spectacles; especially does the mother frequently object to putting glasses on her child, fearing that, once on, they will always have to be worn; others dislike to acknowledge any defect or imperfection of their child's eyes. Though we may sympathize with the child who is compelled to resort to glasses, yet if the eye is imperfect as to its refraction, these imperfections can not be cured by medicaments;

but they should be corrected and the eye thus strengthened by the use of proper spectacles adjusted, and so rendered not only stronger, but largely indemnified against an increase of the myopia and many of the complications likely to arise if it is not so fortified. If care and attention be given to this subject by the present and immediately succeeding generations, this important organ of vision may be so improved, with the body in general, in its anatomical and physiological condition, that future generations will inherit a more perfect organ —one which, to a certain extent, will be immuned against anomalies and their sequlæ.

It is thought that civilization and a high degree of culture are responsible for myopia, and statistics show that myopia is more frequently found in literary persons than in the illiterate, and the reverse is true of hyperopia. This being a fact, there must be some fault in our system of education, mode of living, or habits of life. This is a subject that should interest all, and it *is interesting thinking people, and especially educators, throughout the land*. Much attention is now given to the condition of the school-rooms as to light, ventilation, arrangement of seats and desks, and the length of the study hours.

If myopes are allowed to select their own glasses, they are apt to choose too strong ones. If there is much asthenopia, a blue glass may be prescribed to temper the light. Occasionally, where there is very much asthenopia, tenotomy has to be made, but frequently a slight amount of heterophoria can be overcome by decentering the glass. The myope

with considerable degree of anomaly is predisposed to detachment and hæmorrhage of the retina, particularly at the macula. Such a person should avoid violent exercise or heavy work that requires much lifting or straining.

Myopia is much affected by the nervous condition of the patient, and all excessive indulgence on the part of the parent or progenitor in alcoholic stimulants or in tobacco is liable to find its dire consequences in the impaired vision of the child.

LUXATION FOR MYOPIA.

Should we luxate or extract the lens for the correction of excessive myopia?

This treatment has been suggested by Dr. Priestley Smith.

The extraction of the lens has the same effect as placing a concave glass of 11 D. before the eye. In case of a higher degree of myopia than 11 D., after the lens is extracted, a concave glass of the strength corresponding to the difference between the myopia and 11 D. would have to be used.

In a lower degree than 11 D., with the lens extracted, a convex glass would have to be used corresponding in strength to the difference between 11 D. and the amount of myopia.

In these high degrees of myopia there is usually some disease at the fundus, and it has been my experience that correction of the myopia by the extraction of the lens does not always gain the improvement one might expect.

CHAPTER VIII.

HYPERMETROPIA.

The word *hypermetropia*, or *hyperopia*, comes from the Greek and signifies that the focus of the eye is beyond the measure—retina—or, in other words, it is that condition of the eye whose antero-posterior axis is either too short or its refraction is too low, in consequence of which parallel rays of light as they pass through the dioptric media are not focused upon the retina, without an effort of accommodation, but meet it before they come to a focus, and thus form circles of diffusion (BB, Fig. 105), which give a blurred and indistinct image. To bring these rays of light to a focus on the retina, (dotted lines, Fig. 105), that a sharp image may be gained, a converging lens is necessary.

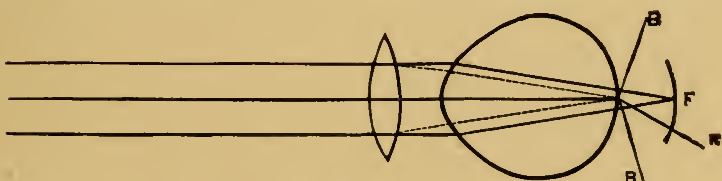


Fig. 105.

The hyperopic eye is an undeveloped eye, being smaller than the emmetropic in all its dimensions. As a rule, there is a deficiency of the rods and cones of the retina as well as of the optic nerve fibres. The disc is frequently of an oval form, simulating astigmatism. The vision, save in rare exceptions, is not equal to that of the emmetropic eye. The nodal point being nearer the retina than in the emmetropic eye, all images are correspondingly less in size.

The axis of the eyeball in the hyperopic eye is shorter than in the emmetropic; and the greater the amount of hypermetropia, the shorter is the optic axis, and *vice versa*.

The accompanying table from Donders shows the amount of shortening of the axis of the eyeball compared with the degree of hypermetropia:

Degree of Hyperopia	Amount of Shortening.	Total Length of Axis.	Degree of Hyperopia	Amount of Shortening.	Total Length of Axis.
D.	mm.	mm.	D.	mm.	mm.
0.0	0.00	22.824 (Normal.)	8.0	2.28	20.54
0.5	0 16	22.67	8.5	2.41	20.41
1.0	0.31	22.51	9.0	2.53	20.29
1.5	0 47	22.35	9.5	2.66	20.16
2.0	0 62	22.20	10.0	2 78	20.04
2.5	0 77	22.05	10.5	2 90	19.92
3.0	0.92	21.90	11.0	3.02	19.80
3.5	1.06	21.76	12.0	3.25	19.57
4.0	1 21	21.61	13.0	3.47	19.35
4.5	1.35	21.47	14.0	3.69	19.13
5.0	1.50	21.32	15.0	3.91	18.91
5 5	1 62	21.20	16.0	4.11	18.71
6 0	1.76	21 06	17.0	4.32	18.50
6 5	1.90	20.92	18.0	4.52	18.30
7 0	2.03	20.80	19.0	4.71	18.11
7.5	2.16	20.66	20.0	4.90	17.92

The common term with the laity for hyperopia is "far-sightedness," a contradistinction from near-sightedness, and the idea is prevalent that the hyperope can see objects at a distance better than an emmetrope—a normal-sighted person. This is a mistake; the hyperopic eye is an undeveloped eye, with sight not up to the normal standard of distinctness either for near or distant objects.

All babies are born hyperopic; the eye may afterward develop into the emmetropic eye, and may

become myopic; and when once any considerable degree of myopia is attained, the eye never again becomes hyperopic except artificially by the removal of the lens, or by the detachment of the retina.

Myopia usually increases by use of the eyes, never diminishes except in later years. Hyperopia rarely, if ever, increases, but frequently diminishes. Myopia tends to increase, while the tendency of hyperopia is to decrease.

Static refraction increases in childhood, but after the period of adolescence it remains stationary. Ivanoff shows that the hyperopic eye has a larger ciliary muscle than the myopic or the emmetropic (Figs. 68, 69, and 70, pp. 78 and 79); the circular fibres, especially, are highly developed, while the myopic eye has few or no circular fibres. It has been demonstrated that the macula lutea is further to the temporal side in the hyperopic eye than in the emmetropic eye, and hence the distance between the disc and the macula is greater, and therefore the angles *alpha* and *gamma* are large; so the hyperopic eye, of necessity, has to exert a greater amount of convergence when looking at near objects than the emmetropic or the myopic eye.

The hyperopic eye of a moderate degree with good power of accommodation may have the normal amount of vision—that is, be able to see $\frac{20}{20}$, and thus pass for an emmetropic eye; but, unlike the emmetropic, which is adjusted for parallel rays or those coming from distant objects, requiring no

effort of accommodation, the hyperopic eye to gain $\frac{20}{20}$ has to exert its power of accommodation. If the hyperopia is of a low degree, the person may suffer no inconvenience from this constant tax, especially if he has to deal mostly with distant objects; but we can readily see that if the eye has to exert its power of accommodation for parallel rays, this exertion must be still greater for divergent rays, or those coming from near objects; and the greater the degree of hypermetropia, the greater is the strain on the ciliary muscle. This is made manifest in what is known as *muscular asthenopia*, *ciliary neuralgia*, or *migraine*.

The hyperopic eye varies in its amount from a fraction of a dioptre to ten or fourteen dioptres; hyperopia of six D., however, is considered a high degree. An eye of 50 D., as spoken of in Dr. Noyes' text-book, page 88, would be such a small eye that it would come under the head of microphthalmus (ophthalmidium) rather than of hypermetropia, and would be sure to be defective in other respects.

In a hyperope of more than four D., the vision is always less than normal. Hypermetropes with less than 3.50 D., with good accommodation, as a rule, have $\frac{20}{20}$, or normal vision. Frequently convex glasses do not improve their vision, although the ophthalmoscope will show a varying amount from one to four or five D. Many of these people will accept a weak convex glass, say from 0.50 D. to 1 D., which will bring their vision up to $\frac{20}{20}$; some require not more than a fraction of a dioptre to gain normal vision, but will yet accept a

stronger glass, as 1 D. or 2 D., or even more. Usually, these hyperopes under atropia require a much stronger glass,—for instance, 3 D. or 4 D.,—and if the power of accommodation is fully set aside, the glass that will give them the greatest amount of vision indicates the amount of their hypermetropia.

The strongest glass that they require without the use of a mydriatic indicates the *manifest hypermetropia*. The difference between this glass and the one required after the power of accommodation is fully set aside shows the amount of *latent hypermetropia*.

The *manifest* is usually apparent without a mydriatic; the *latent* is revealed by it. As a rule, the latent is of greater amount than the manifest. These two constitute the *dynamic refraction*. The manifest is usually corrected for a time, at least, by the power of accommodation (dynamic refraction); but if the dynamic is much exercised, as for reading, etc., the eye becomes tired and a train of asthenopic symptoms appears, demanding relief.

SYMPTOMS.

Subjective Symptoms. The patient complains of pain in the region of the eye, sometimes in the center or back part of the eyeball, but more frequently through the temple and over the brow. The pain is occasionally referred to the back of the head, and may be accompanied by nausea and vomiting. The patient will often speak of a frontal headache, which by the French has been called *migraine*. The neuralgic headache and the intense pain through the temple and over the brow, streaking down the nose and cheek, are usu-

ally to be attributed to hyperopia. The patient will often speak of being unable to use his eyes for a considerable length of time without weariness, drowsiness, drooping of the lids, and inclination to close them; and if he persists in his work for a great length of time, the pain becomes severe, the page blurs, letters are indistinct and dance upon the page, the lines skip over one another, and the reading has to be discontinued; but if he rests his eyes for a little time, batting his lids or closing them, thus relaxing his accommodation, he is able to resume the work; if he persists, however, the same symptoms repeat themselves, and finally he is obliged to desist altogether. The above symptoms constitute the condition known as *asthenopia.*

Objective Symptoms. The hyperopic eye, as already said, is an undeveloped eye; it is usually deeply set in the orbit; however, in some rare cases the hyperopia is due to a low refractive power, and not to the length of the eyeball, and the eye is fully up to the standard in size in all dimensions. As a rule, the hyperopic eye is not so clear and bright in appearance as the emmetropic eye, being slightly red, as there is more or less hyperæmia, especially in the ciliary region; this hyperæmia is probably due to the constant effort of accommodation.

It is sometimes found that a hyperope who can see the last letters on the card at twenty feet, or whose vision is apparently normal, will accept a convex glass, the glass sharpening his vision and relieving the eye. This always indicates hyper-

opia. Sometimes the hyperope with vision of $\frac{20}{20}$ will accept a glass as strong as 3 or 4 D., which shows a high degree of facultative accommodation. As a rule, in the hyperopic eye the pupil is smaller and the person seeks strong light. If the hyperope does not wear glasses in early life, he is compelled to put them on for reading sooner than the emmetrope; in other words, he becomes presbyopic sooner than the emmetrope. A hyperopic person may worry on and continue to use his eyes for years without the aid of glasses, but in case of ill health the power of accommodation gives way and the anomaly becomes suddenly more manifest.

CAUSE.

Hypermetropia is a congenital defect, due to a shortened visual axis, or deficiency of the lens. In old age it may be due to a flattened condition of the lens, and in glaucoma to a flattened condition of the cornea due to extension of the globe.

That hyperopia is hereditary, there is no doubt. This can be demonstrated daily in our practice.

In women any uterine trouble may provoke asthenopic symptoms. Some women during the catamenia or during pregnancy have more or less asthenopia. Endometritis is frequently provocative of ciliary neuralgia.

The conformation of the orbit has much to do with the development of the eye, as to its being emmetropic, myopic, or hyperopic; especially is this true in many cases of anisometropia. Ametropia is frequently associated with asymmetry of the cranium and face.

The contour and shallowness of the orbit, the dolicocephalic cranium, and the narrow face have some influence on the development of this eye.

DIAGNOSIS.

The acceptance of a convex glass for distant objects is positive proof of hyperopia, and even the acceptance of a weak concave glass does not disprove it, as frequently the hyperope has spasm of accommodation which simulates myopia, and a concave glass improves vision, whereas the person is really hyperopic. In such cases it is always necessary to set aside the power of accommodation, relaxing the spasm. To do this, it is frequently necessary to use a mydriatic for some days, applying it several times daily before the spasm can be completely overcome. A one per cent solution of sulphate of atropine has so far proved the only reliable mydriatic in my practice. When the spasm is thoroughly relaxed, and the power of accommodation is completely under control, it will be found that concave glasses no longer improve vision, but convex do.

There are several methods for detecting hyperopia, some of which we here consider.

CUIGNET'S TEST. One of the readiest means without the mydriatic is *Cuignet's method*, or the *shadow test—skiascopy*, of which we have already spoken in Chapter VI. As the light is cast into the eye with a flat mirror, the shadow flits over the pupil in the same direction that the light is thrown, whereas the opposite obtains in myopia.

PRISOPTOMETRY (page 94). Prisoptometry is another test, although this is not so accurate as

the shadow test, because the power of accommodation may interfere. If the power of accommodation, however, is set aside, the test is reliable. In hyperopia the false disc (*c*, Fig. 81, page 95) is separated from the true, and if it is a case of simple hyperopia, the space remains of the same width all the way around as the prism is revolved.

CHROMATIC TEST (Plate VII). The chromatic test is also convenient for revealing hyperopia; the border of the flame with this test appears red while the center is blue, the reverse being true in myopia. The convex glass that will neutralize the flame indicates the degree of hyperopia.

SCHEINER'S TEST (page 127). This consists, in brief, in requiring the person to look at a flame through a card with two perforations, which must be so near together that rays passing through them will enter the pupil. In the hyperopic eye, two sets of rays will reach the retina before meeting, each set forming an image of the flame. The greater the hyperopia, the further apart will be the images formed (Fig. 101, page 128). These are projected outwards as crossed images, and the patient sees two images of the flame. The convex glass which, placed behind the card, causes the flame to be seen singly indicates the degree of hyperopia. If a piece of red glass be placed behind the right aperture of the card, the left one of the two images will appear red, the other one white. The opposite obtains in myopia.

TEST WITH THE OPHTHALMOSCOPE. This is one of the readiest and most reliable tests. If the eye is viewed by the ophthalmoscope from a dis-

tance of twelve or fourteen inches, the blood-vessels at the fundus of the observed eye will seem to travel in the same direction in which the observer moves his head.

If the eye is viewed from a near point, the power of accommodation of both examiner and examined at rest, a convex glass will be necessary to bring out the details of the fundus distinctly. The higher the degree of hyperopia, the stronger will be the glass required. The strongest convex glass with which you can distinctly see the fine blood-vessels at the margin of the disc or those near the macula indicates the amount of hyperopia and the glass to be prescribed. (See Chapter VI, page 96.)

PRINCIPAL AND MOST RELIABLE TEST.

TRIAL GLASSES (Fig. 106). The most reliable test and the one usually employed by oculists is the trial glasses from the trial box. If the degree of hyperopia is more than 2 D. or 3 D., a convex glass will improve vision. If it is a low form of hyperopia, the convex glass frequently does not improve but may diminish the vision, while a weak concave glass may improve. As above said, in such a case the power of accommodation must be set aside by mydriasis. However, it is not always practicable or safe to employ a mydriatic; as, for instance, those patients who are dependent upon their eyes for a livelihood, as seamstresses, clerks, book-keepers, teachers, artists, etc., whose positions can not be readily filled by others, and who, if they are laid off from work for a few days, are liable to lose their positions. In such cases,

it may be best to ascertain as near as possible the amount of hyperopia and prescribe glasses without mydriasis. Yet there are many exceptions where there is persistent asthenopia, due, perhaps, to some hidden heterophoria or astigmatism, which can be

Fig. 106.

revealed only by employing a mydriatic, and in these cases the correction and relief to be gained by the drug and proper glasses are paramount to all other considerations. The drug does not only disclose the entire hyperopia, but it

also acts as a remedy by resting the ciliary muscle. Where there is persistent spasm of accommodation, it is frequently found necessary to keep the person under mydriasis for ten days or two weeks before the spasm will give way entirely and the true condition be revealed. Again, the mydriatic is not to be used indiscriminately. In middle-aged or old people it may provoke that most formidable disease—glaucoma. Yet, as before said, it is very important to use it in most cases, especially with the young, for if a mistake were made and concave glasses used, injury to the eye would result. Frequently evils arise, such as cyclitis, choroiditis, staphyloma, etc., from individuals selecting their own glasses or incompetent dealers selecting for them.

With the test in question, the patient should be placed at twenty feet distant from the test card (page 87) and the vision of each eye taken separately, as in myopia. The right eye being tested first, the left is covered by an opaque disc, placed within the spectacle frame. The amount of vision of each eye should be recorded.

The glass that will give the best vision, the power of accommodation being paralyzed, will show the degree of hyperopia, and, as a rule, may be prescribed. Sometimes, however, it is found that the patient will not accept the full correction, and only a part of the hyperopia is then to be corrected, the remainder to be taken care of by the power of accommodation. The left eye should be tested in a similar manner to the right.

Ask the patient to read down the card. Fre-

quently, if you ask him whether he can see the letters on the card, he will answer in the affirmative, declaring that he can see the smallest; but the statement of the patient should never be taken as definitive, he should be required to read aloud the letters from the top down. Often, we find that those patients who say they can see the small letters have a vision of only $\frac{20}{40}$, or even much less, as $\frac{20}{80}$, or they may see well with both eyes uncovered and be blind in one, or the two eyes may vary in acuteness of vision. They may be able to see some of the smaller letters, but others they will miscall; as, for instance, they may call C O, G O, and *vice versa;* F E or T, etc., which is an evidence of a certain amount of astigmatism. These patients are sometimes able to see at a glance letters that become dim if the eye is fixed for any length of time upon the card, showing hypermetropia only partially or momentarily controlled by the power of accommodation. The patient then should be required to read down the card as far as he is able to distinguish the letters; then a weak convex glass, say 0.50, 0.75, or 1 D., should be placed before the eye, continuing with stronger until the highest number is reached that will give the greatest amount of vision. In like manner, test the other eye, covering the former with an opaque disc. It is my custom to examine always the right eye first and make a careful record of the vision without the use of glasses, and then the amount of sight obtained by their aid. If I use a mydriatic, I am careful to record the amount of vision without the mydriatic, and the strongest

glass required to give the greatest amount of vision. Then, after the use of the mydriatic, I record the vision again without the use of the glasses, and then the amount gained by their use. In this way, I am able to see at a glance the amount of manifest as well as the latent hyperopia, also the facultative hyperopia, and the glass giving the most benefit. In cases where there are a considerable amount of asthenopia and other sequelæ, it is generally more satisfactory to the oculist, and usually to the patient's advantage, to use a mydriatic at once. However, as has been said, the inconvenience and the detriment that may result to the person who is dependent upon his eye-sight for a livelihood, and who, from being obliged to lay aside the work for a time, jeopardizes his position, should not be disregarded.

Mydriasis can be accomplished, usually, by apprising the patient of its necessity and allowing him to arrange accordingly.

PROGNOSIS.

Hyperopia can be corrected, but may not be entirely cured. In correcting hyperopia, the strain is taken off the eye, and the organ is put in a better condition for a more perfect development. In a low form of hyperopia in a young person, we may look for a diminution of the anomaly, and a final development to a perfect emmetropic eye. I have frequently found this to be true in young people, especially school-children and students, they in after years by the temporary use of glasses becoming absolutely emmetropic.

Often in low degrees of hyperopia, especially among school-children and students, after the school work or the college course is over, and the eyes are no longer required for so much continuous near work, the glasses may be laid aside; but if they are not used during the course of study, the student suffers from asthenopia and frequently has to discontinue his studies.

SEQUELÆ.

As we have said, the hyperopic eye, from its anomaly, is of necessity compelled to use the power of accommodation for distant as well as for near objects. The nearer and smaller the object, the greater must be this muscular exertion; and if the hyperope is compelled or allowed thus to use his eye, complications are liable to follow. By the continued effort of accommodation the ciliary muscle and contiguous parts are congested; and thus dire results may follow. The ciliary muscle, from its great effort in heightening the power of refraction, is most likely to be affected in one way or another. Frequently, we have what is known as *spasm of accommodation*, which is a partial paralysis or paresis of the ciliary muscle; and instead of the lens springing back to its normal position and condition when distant objects are looked at, the eye is for the time, at least, myopic, and may become permanently so, if rest or treatment is not given.

Other manifestations of abuse or overuse of this muscle present themselves in the form of neuralgia, called ciliary neuralgia, pain through the temples, over the brows, and deep in the eye. Con-

vergent strabismus is one of the most frequent sequences of this anomaly.

The hyperope is especially susceptible to diseases of the appendages of the eye, particularly to those of the conjunctiva and the lids. It is now a conceded fact that hyperopia is often a primary cause of marginal blepharitis, of trachoma, and of phlyctenular keratitis; or, if not a direct cause, it exerts its influence in aggravating these affections, and prevents a permanent cure if the hyperopia be not corrected by glasses. The hyperopic person is frequently annoyed by hordeola, chalazia, trachoma, tinea tarsi, ciliary hyperæmia; but more especially is hyperopia responsible for convergent strabismus and heterophoria in many of its forms. It is thought to be a frequent cause of that most destructive disease—glaucoma.

Again, it is believed that the hyperopic eye is more frequently cataractous than the emmetropic.

TREATMENT.

In hyperopia, as in myopia, the eye should not be overtaxed and the young child should not be allowed to enter school too early. Out-of-door life and open-air sports should be encouraged, and in-door, sedentary, and studious habits restricted

The hyperopic eye should be relieved and strengthened by the convex glass which corrects the anomaly. If the hyperopia is of a low degree, as 1 D., or a fraction thereof, and in a young person, the power of accommodation may be ample to compensate for the lack of refraction, especially if the eyes are not overtaxed; but there is always a higher

degree of hyperopia than is apparent, the power of accommodation concealing a portion.

Frequently it will suffice to correct the manifest hyperopia, allowing the accommodation to compensate for the latent, the patient experiencing more comfort when using some muscular effort than when he is entirely relieved by glasses. However, there are individual cases where, from some enervation or from a very weak condition of the ciliary muscle, the whole amount—manifest and latent—must be entirely relieved, or, in other words, the hyperopia *in toto* must be corrected, even though it be of a slight amount. To make this correction, the power of accommodation should be entirely set aside, and this may not be fully accomplished until after the repeated use of the mydriatic for perhaps several weeks.

After the degree of anomaly has been ascertained, the strongest convex glass that will give the highest amount of vision should be prescribed, and the patient be instructed to use these glasses continuously for distant as well as for near objects. Especially should this be insisted upon with those who have had spasm of accommodation and muscular asthenopia. With these low forms of hyperopia, heterophoria in one or another form is frequently associated. This insufficiency of the extrinsic ocular muscles should be looked for, and, if it exists, corrected. (See Chapter XI, Heterophoria.)

In a high degree of hypermetropia, it is best to correct some, at least, if not all, of the latent, as well as the manifest. The patient will not, as a rule, accept the full correction at first. Then it

may be best to correct the manifest and perhaps some of the latent, allowing him to wear the glassses for a time until his power of accommodation shall be so relaxed as to permit the full correction.

The strength or condition of the ciliary muscle or power of accommodation must be taken into consideration, whether all or a portion of the latent hyperopia be corrected. If this facultative accommodation is well pronounced, as in the following case, it is only necessary to correct the manifest:

CASE. The patient was a young lady, M. J—, aged twenty, blue eyes, perfect physique, weighing 130 pounds, a school teacher from Sioux Falls, South Dakota, who visited me August 19, 1890, complaining of pain in and about the eyes, especially through the temple and over the brow, and of not being able to read for any length of time without the lines blurring and letters running together, but more especially did she complain of frontal and temporal headache. Examination revealed V. R. E. $\frac{20}{30}$, V. L. E. $\frac{20}{30}$; with plus 0.50 D., vision of either eye equaled $\frac{20}{20}$; she could also get with plus 1.50 D. $\frac{20}{20}$. Ophthalmoscopic examination, however, showed a much higher degree of hyperopia, most of which was concealed by the dynamic refraction. A one per cent solution of sulphate of atropine was dropped into the eyes, and under the full effect of the mydriatic the vision was again taken. I then found that the patient had to come within five feet in order to see the largest letter on the card with either eye; or, in other words, that the static refraction or her real vision, uncontrolled by the power of accommodation, was only

$\frac{5}{200}$. With a plus 5.50 D. combined with plus 0.25 D., C· 90°, for either eye, vision was $\frac{20}{20}$.

In slight degrees of static refraction the dynamic refraction is usually sufficient to compensate or neutralize the hyperopia, but in higher degrees we do not expect it. In the case in question nearly the whole amount of hyperopia by an effort of accommodation could be corrected, and the eye rendered, as it were, emmetropic. Now, if we grant that there was a manifest hyperopia of 0.50 D., we still have here a dynamic refraction of 5 D., all of which was corrected by the power of accommodation.

At another examination of this patient August 25, 1890, vision of either eye was $\frac{20}{20}$, but at this date she could relax the dynamic refraction sufficiently to still get $\frac{20}{20}$ with a plus 3 D.

In prescribing glasses for this patient I only gave plus 2 D., combined with plus 0.25 D., cylinder, axis in 90° for each eye, allowing her to still use more than half of her dynamic refraction; and these glasses have, up to this time (1896), given perfect satisfaction. Had the dynamic refraction been less with the same degree of static refraction, I should have prescribed a much stronger glass, and in all probability the patient would have required a stronger one.

Formerly it has been my custom not to correct the full amount of dynamic refraction, allowing a portion to be supplemented by the power of accommodation for a time, at least, after which the full correction was frequently given. It is, as yet, a debated question whether the full correction should be given at first, thus compelling the patient to

adapt himself to the use of the glass of full correction at once, or correcting a portion at different times as the latent gradually becomes manifest.

Of late, I have been inclined to believe that, as a rule, it is best to correct the full amount at once, rendering the patient emmetropic, as it were, compelling him to exercise his power of accommodation only for near objects or divergent rays as the emmetrope does; as sooner or later the full correction has to be made, and we thus save time and expense to the patient and much vexation of spirit to the oculist; besides, the patient is relieved in a much shorter time of his asthenopia than if the time be prolonged before the full correction is given. However, no fast and fixed rule can here be adhered to, and the oculist may use his judgment in determining what to do. The patient will frequently object, at first, to the full correction, but if he will persevere in the use of these glasses, they will prove eventually more satisfactory than those partially correcting; the asthenopic symptoms subsiding, the glasses will be worn with much satisfaction.

It would seem that many hyperopic eyes in their normal condition demand that a certain amount of static refraction be used for all objects—distant as well as near, and if the full correction is given, the person will complain of asthenopic symptoms, and this glass of full correction does not give satisfaction; but if a weaker one is given, correcting in part the hyperopia, the eye being allowed to use some of the static refraction for distant objects which it seems to demand, satisfaction is given.

It is always advisable, if possible, to bring the two eyes up to the same degree of vision, and with the same strength of glass, prescribing, if possible, the same strength of glass for each eye, rather than a slight difference between the two. However, in anisometropia each eye must be fitted irrespective of its fellow. As more or less astigmatism is liable to exist with hyperopia, one should always look for it, and, if there is any, correct the same. If, however, a spherical glass, with the power of accommodation set aside, will give $\frac{20}{20}$, there is no need of cylinders. However, where a cylinder will give $\frac{20}{20}$ it frequently has the effect of relieving the asthenopia, whereas a spherical glass, giving the same amount of vision, will fail to relieve the asthenopia.

In adjusting glasses to the hyperope, as in other forms of ametropia, especially with high degrees, care should be exercised in fitting them to the face; they should be accurately centered vertically as well as horizontally (unless decentration is desired for its prismatic effect). In strong convex glasses the least inclination in the plane of the glass produces an astigmatic effect, and any slight decentration will produce the effect of a prism, and may cause heterophoria.

In a high degree of hyperopia, it is advisable, in some cases, to prescribe two pairs of glasses, a weaker for distant and a stronger for near. From distant objects, the rays of light meet the eye as parallel, and their focus, as they pass through the dioptric media, is in front of the focus for rays coming from near objects which are divergent; and hence, the former condition would not require

so strong a glass as the latter. But, if the power of accommodation is good and the eye rendered emmetropic by a glass, there is no further need of a second pair.

By the many examinations made of the eyes of school-children, soldiers, and babies, it has been found that the per cent of hyperopia is much larger than that of emmetropia, and some have concluded from this that the moderately hyperopic eye is to be looked upon as the typical or normal eye, rather than the emmetropic.

Dr. Roosa says that in case of compound hyperopic astigmatism of a low degree, he corrects the astigmatism only, leaving the hyperopia to the power of accommodation. I have frequently noticed myself that in a low degree of compound hyperopic astigmatism, if I correct both, giving a sphero-cylindrical glass, this glass does not always prove satisfactory; and if I change, correcting only the astigmatism with a simple cylindrical glass, this glass is worn with much satisfaction; as, for instance, in a case of compound hyperopic astigmatism, say 0.50 D. in the vertical (90°) and 1 D. in the horizontal meridian (180°), instead of giving a 0.50 D. spherical combined with 0.50 D. cylinder with axis of the cylinder in the 90th meridian, I simply prescribe the cylinder, leaving the 0.50 D. of hyperopia uncorrected. But in a higher degree of hyperopia with astigmatism, simply correcting the astigmatism will not suffice.

Although we may feel that it is oftentimes advisable to deduct from the glass of full correction in simple hyperopia or myopia, we would never think of making any deduction from the cylinder required to correct the astigmatism.

CHAPTER IX.

ASTIGMATISM.

As has been stated in Chapter IV, the anomalies of refraction are of two kinds; namely, myopia and hyperopia. In these two forms we find that the anomaly is of the same kind and amount throughout all the different meridians of the eye. There are eyes, however, which are emmetropic in one of the principal meridians while the other is ametropic. Again, there are others which have some form of ametropia in both principal meridians, but of a greater amount in one than in the other. Still, there are others in which one meridian is of one form of ametropia, while the opposite is of the other form.

These phenomena are due to a non-symmetrical curvature of the cornea, sometimes of the crystalline lens, and this asymmetry of curvature is called *astigmatism.* The term signifies that rays emanating from a point are not reunited at a point; or, in other words, the refractive media of the eye are not equal in all their meridians, the focal distance of one being greater than that of its opposite; that is to say, the refractive meridians are not symmetrically arranged around one axis.

Astigmatism was accidentally discovered by Young, when, looking through the telescope, he noticed that the hair-line or wire stretched across

the instrument was seen only in certain meridians, as the telescope was revolved.

If astigmatism be of the cornea it is called *corneal astigmatism;* if it is of the lens, it is called *lenticular*. All eyes, however, as has been proven by Donders, are slightly astigmatic, since the cornea in the so-called normal or emmetropic eye does not refract equally in all its meridians, and the focal distance is generally shorter in the vertical than in the horizontal; and on this account, fine vertical lines are seen at a further distance than horizontal ones, and the latter can be seen closer than the former. This proves the above statement that the points of the refracting meridians are not symmetrically arranged around one axis.

In speaking of the principal meridians in connection with astigmatism, we usually mean the 90th and the 180th, as these are the ones that are most frequently in error; however, the principal meridians may be at almost any degree, but the two erring meridians are always at right angles to each other unless it be irregular astigmatism, which can not be corrected. If one meridian is at 45°, the other must be at 135°; if one is at 75°, the other is at 165°; if one is at 105°, the other is at 15°, etc. A slight difference in the two principal refracting meridians in the so-called emmetropic eye is to be disregarded, needing no correction; but if the difference is considerable, it will provoke asthenopic symptoms and should be corrected. Astigmatism is quite a frequent anomaly, and is often responsible for asthenopia.

The following figures illustrate this anomaly. In Fig. 107 we imagine the light to come from a given point (L), and pass through the refractive media, being focused somewhere on the axis behind.

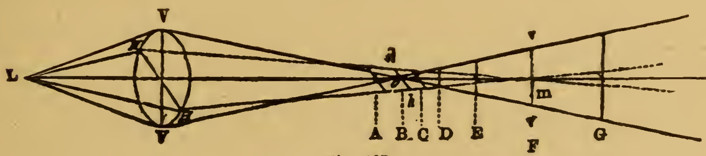


Fig. 107.

We consider here only the vertical (VV) and the horizontal (HH) meridians, which we shall call the principal meridians. Rays of light coming from L (Fig. 107) would meet the eye as a cone of light, and we find that the rays which pass through the vertical meridian (VV) are converged more rapidly than those that pass through the horizontal (HH), while both are approximating the axis. Those of the vertical meet the axis in front of those of the horizontal, and before either meet we have the elliptical figure A (Figs. 107 and 108).

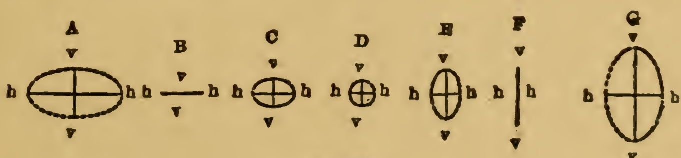


Fig. 108.

A little further on the vertical have intersected, while the horizontal are still some distance apart, and we have the horizontal line, B. Beyond this point, the vertical diverge, the horizontal approach, and there is a small horizontal ellipse, C. Beyond this point, nearer the retina, the vertical are slightly more divergent, while the hori-

zontal are nearer together, the distances between the divergent vertical and the convergent horizontal are equal, and the circular figure, D, results. Still further on, the vertical are more divergent, the horizontal are more approximated, and we have the vertical elliptical figure, E. Further on, the horizontal have come to a focus and the vertical are more separated, and we get a vertical line, F. Still beyond this point, both vertical and horizontal diverge, and a large vertical ellipse, G, is the result.

The interval between the points of intersection of the vertical and that of the horizontal is the *focal interval* (*om*, Fig. 107). At the center of the focal interval, the amount of divergence of the vertical equals the amount of convergence of the horizontal, and consequently the rays form a small circle. The astigmatic person regulates his power of accommodation so as to bring the middle point of the focal interval upon the retina, and so gets the smallest circle of diffusion. At the very best, the image is not sharp, as there is no true focus, there being only small circles of diffusion. The image is more distinctly seen here than at the anterior or posterior extremity of the focal interval.

In Figure 108 the letters A, B, C, D, E, F, and G correspond to the same letters in Figure 107. The rays which lie in the plane of the vertical meridian (VV, Fig. 107) are brought to a focus at *o*, while the rays which lie in the plane of the horizontal meridian (HH) are not yet united, but form the horizontal line *hh*, the *anterior focal line*. The rays in HH are united further back at *m*,

where the vertical rays form the vertical line vv, the *posterior focal line.* The aberration which is due to a difference in the focal distance of the two principal meridians is called *regular astigmatism*, and depends upon the curvature of the cornea, whereas the aberration which is due to a difference in the refraction in one and the same meridian is called *irregular astigmatism*, and is usually due to ulceration of the cornea or a peculiar condition of the lens. This form can not be corrected by glasses and it frequently gives rise to monocular polyopia.

The greater the difference in the refraction of the principal meridians the greater will be the circles of diffusion, and consequently an increased indistinctness of vision. If there is much astigmatism, the acuteness of vision is impaired for both near and distant objects.

Regular astigmatism is of three forms; namely, *simple*, *compound*, and *mixed.*

Simple astigmatism is where one of the principal meridians is emmetropic and the other ametropic (either myopic or hyperopic).

Compound is where both are either myopic or hyperopic, but one meridian is of a higher degree of ametropia than the other.

Mixed astigmatism is where one of the principal meridians is myopic, the other hyperopic. Either the myopia or the hyperopia may predominate.

CAUSE.

Astigmatism is usually congenital, frequently it is hereditary. Occasionally it follows an operation for the extraction of cataract, or it may be a sequel

to traumatism of the cornea. Astigmatism occurring after the extraction of cataract may be due to the removal of the lens, which, from its asymmetry previous to the extraction, corrected the asymmetry existing in the cornea. It has also been noticed that astigmatism has been corrected after the extraction of cataract, showing that the astigmatism was of the lens and not of the cornea. Lenticular astigmatism, however, is very rare.

The usual cause of astigmatism after extraction of the lens is due to the change of the curvature of the cornea from the union of the wound, especially if there has been imperfect coaptation of the lips of the wound after extraction.

It is thought that the location of the incision as to whether it is scleral or corneal influences the amount of astigmatism.

Ulcers, abrasions, wounds, etc., of the cornea are among the causes of irregular astigmatism.

SYMPTOMS.

The vision of a person with astigmatism of any considerable amount is below the normal. The astigmatic person is frequently in the habit of holding the head to one side in order to gain a sharper and more distinct image of the object. He frequently complains of frontal and temporal neuralgia. He refers the pain more especially to the deep parts of the eye, the back of the eye, and with the ophthalmoscope there can almost always be seen some pulsation of the veins at the disc, evidencing intraocular tension.

Astigmatism is thought to be responsible for epilepsy, vertigo, and different forms of chorea, more especially that form in which there is spasm of the facial muscles—a peculiar twitching and jerking of the face, corners of the mouth, and muscles of the lids. Statistics show that the majority of inmates of the insane asylums and prisons have some form of ametropia or heterophoria.

Astigmatism is evidenced by "nervousness", irritability, uneasiness, and discontentedness; especially is this the case if the astigmatism is in other than the vertical or the horizontal meridians.

With the ophthalmoscope (concave mirror), by

Fig. 109.

the direct method, viewing from a distance of twelve or fourteen inches, the retinal vessels appear more distinct in a certain meridian than elsewhere; and if it is a case of hyperopic astigmatism, they seem to travel in the same direction that the head of the observer is moved; the reverse is true in myopic astigmatism. If the eye is approximated, and the fundus viewed by this method, the disc, instead of appearing circular, is seen oval, and its longer diameter may be in any meridian (Fig. 109);

it may be in the vertical, horizontal, or any meridian between these two.

If it is myopic astigmatism, the disc by this method always appears larger; but if viewed by the indirect method, the disc appears smaller, whereas the reverse is true of hyperopic astigmatism. Where the patient refers the pain especially to the eyeball or to the back of the ball, I have almost invariably noticed pulsation of the veins near the center of the disc.

DIAGNOSIS.

It is not, as a rule, difficult to recognize this anomaly. In the diagnosis, a settled line of examination must be adhered to, or great confusion will arise.

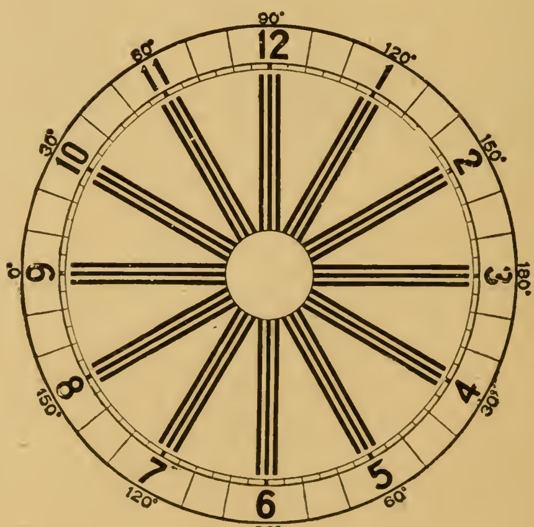


Fig. 110.

In the first place, we must carefully examine the acuteness of vision. If it is below $\frac{20}{20}$, the nor-

mal standard, we should try to raise it with a concave or a convex glass. If we fail in doing so, astigmatism may be suspected. Have the patient look at the dial (Fig. 110) twenty feet away. If he is astigmatic, lines in a certain meridian will appear brighter and more distinct than in others. If it is a case of simple hyperopic astigmatism (the hyperopia being in the horizontal meridian), the lines, as a rule, will appear more distinct in the vertical or near the vertical than in the horizontal. However, the reverse may be true, which is against the rule. In case of simple myopic astigmatism (the myopia being in the vertical

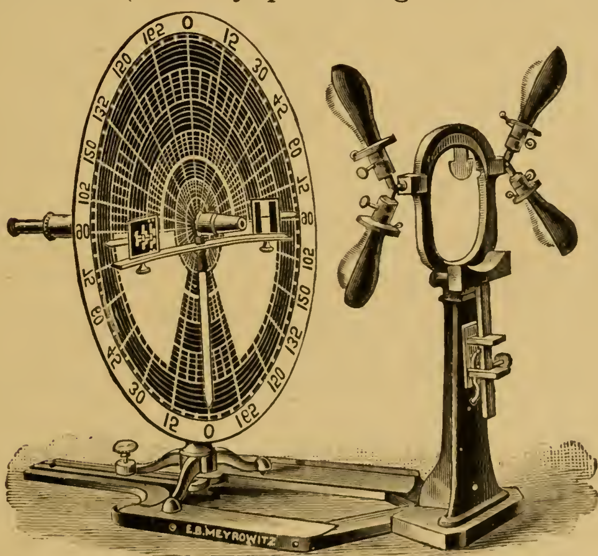


Fig. 111.

meridian), the person usually sees the lines in the horizontal or those near the horizontal brighter and more distinct than those in or near the vertical; but the reverse, as in the former case, may be true, which is also contrary to the rule. The

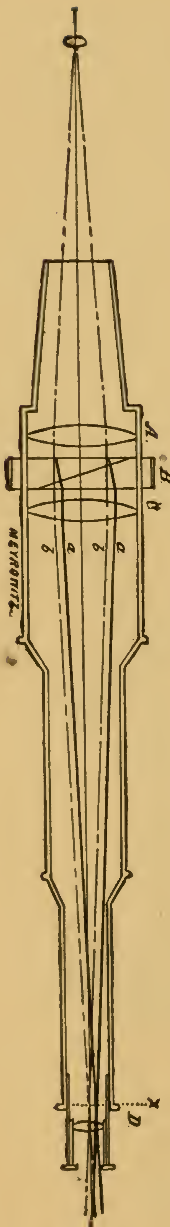


Fig. 112.

astigmatic person makes mistakes in some letters; for instance, he calls G C or O, Y T or V, O C, N H, B R, and *vice versa*. This shows that only parts of the letters which are in certain meridians come out distinctly.

The *astigmometer* (*ophthalmomètre*) is an incontrovertible means of recognizing corneal astigmatism, and it also indicates the meridian; it does not only this, but in many cases it approximately shows the amount without a mydriatic. It is also a means of measuring the radius of the cornea. The *Javal and Schiœtz ophthalmomètre* (Fig. 111) is the most scientific instrument for this purpose yet placed in the hands of the ophthalmologist.

It consists of a large disc spaced off by meridians into degrees from 1 to 180 from above (0) downward to the right, and from below upward to the left, making 360° altogether, and has concentric circles one degree apart, the radius of the disc being divided into 45 degrees. The figures on the disc are inverted, but as seen reflected from the cornea are upright. The disc is supported on a tripod, and through its center is placed a telescope containing a

Nicol's prism (B, Fig. 112) and two bi-convex lenses (A and C), which have the effect of doubling the image. At the extremity of the telescope is an ocular (D) and two crossed wires, both of which are seen distinctly when the instrument is in focus. In front of the disc upon the telescope is attached a curved, horizontal bar (Fig. 113) having a radius of curvature of 27 cm.

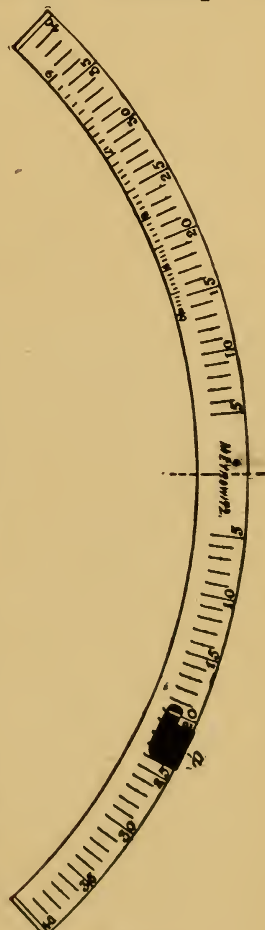


Fig. 113.

By this arc we are able to measure the radius of curvature of the cornea. Upon the arc are placed two plaques (A and B, Fig. 114) and a pointer (C). The plaque A is divided into steps. The pointers *bb* extending from the plaques show the axis of the cylinder in hypermetropia; and if myopia exists the long pointer C marks the axis.

In front of the disc and about fourteen inches away is an adjustable chin-rest or frame, to which may be attached the electric or gas light. The incandescent electric light is the best, as it does away with the objection of heat from the gas light.

The patient under examination should direct the eye steadily upon the telescope, the other being covered by an opaque disc. The

forehead should rest firmly against the frame and the head be supported by the chin-rest (Fig. 115).

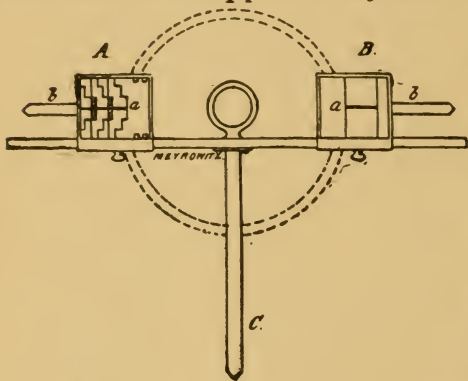


Fig. 114.

The disc with its division and the two plaques on the horizontal bar (Fig. 115) are seen by the observer through the telescope as reflected from the cornea. The prism has the effect of doubling the images, and the two plaques on the bar are

Fig. 115.

seen as four; the two central ones are the ones to be regarded (Fig. 116). The plaque with the steps is movable, and when the instrument is in focus, this should be moved up so that the edge of the notched parallelogram touches the edge of the other, and that the horizontal line of one is continuous with the other, *ab*. If the lines cannot be made to be continuous, it suggests a conicity of the cornea and irregular astigmatism.

After the adjustment of the instrument and the

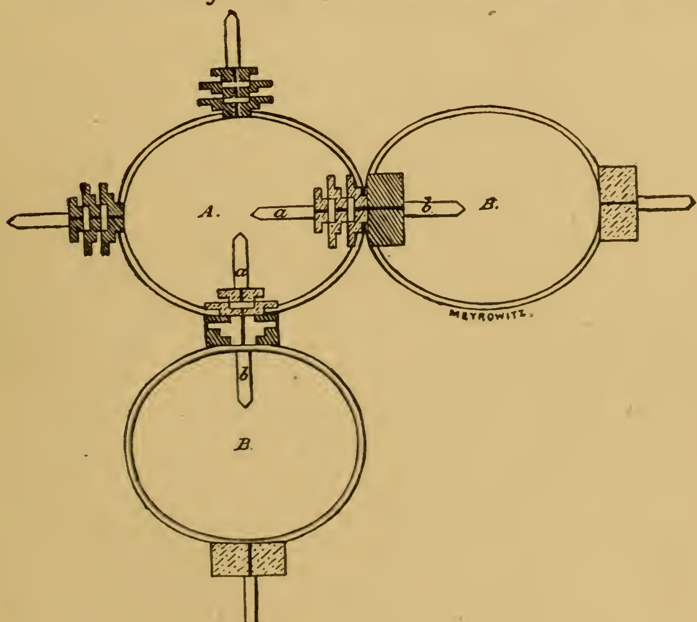


Fig. 116.

plaque, turn the telescope with the bar, and if the two plaques remain tangent throughout the differ ent meridians as the telescope is rotated, there is no astigmatism indicated; but if the steps overlap the other plaque in a certain meridian, astigmatism exists, and the pointers indicate the meridian.

The overlapping of one step indicates 1 D. of ametropia. With this instrument it is possible to ascertain even a very slight amount of astigmatism, as a slight overlapping of the step, as one-fourth, would indicate 0.25 D., providing the instrument is accurately and well made (if not, it is unreliable and misleading).

Often, winking or closing the lids, thus varying their pressure upon the cornea, changes its curvature, giving an illusive impression of astigmatism.

In a case of simple astigmatism, the plaques may be seen as tangent in the horizontal meridian while the steps overlap in the vertical (Fig. 116); or they may separate as in Fig. 117.

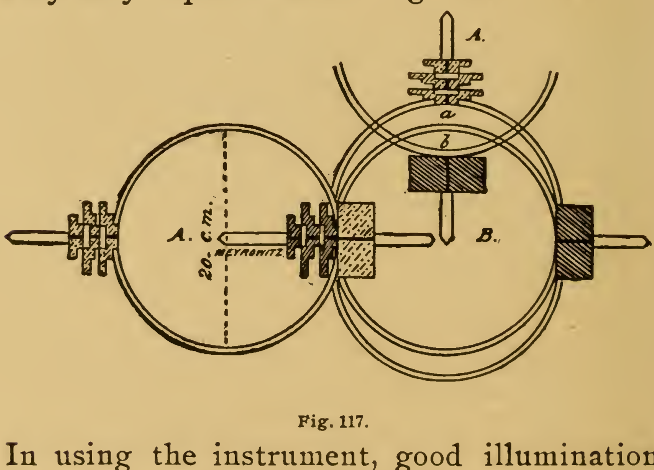


Fig. 117.

In using the instrument, good illumination is imperative. Sunlight is the best; but to make the instrument useful in all weather, artificial light should be provided, and this light should be on a level with the bar, and reflected by shades, so as to thoroughly illuminate the whole disc. It is imperative that the patient's head be properly sup-

ported by the chin-rest and the frame, and that the eye be held perfectly still, as the slightest movement will throw the image out of focus, and false impressions be received.

F. A. Hardy & Co., of Chicago, manufacture an astigmometer, constructed optically on exactly the same principles as the Javal & Schiœtz instrument, differing only in the arrangement of the arc carrying the mires, and the substitution of a perfectly plain disc, which rotates with the arc, in place of the stationary graduated disc employed on the Javal & Schiœtz instrument. The advantages of this mode of construction are that the arc, being centrally attached to the tube which carries it, always remains at the angle at which it is turned and does not fall out of position when the operator releases it, and the operator also is not confused by the multiplicity of images produced by the reflection of the disc on the French style, but obtains a perfectly clear image of the mires, which is the practical part of the instrument. They also abandon the cross-hairs for focusing the eye-piece, since the focusing of the eye-piece is a correction of very little value in the use of the instrument, the effect of an error of one dioptre in the eye of an observer being equal only to about $\frac{1}{500}$ part of a dioptre in the reading of the astigmometer, and by removing the cross-hairs an obstruction to the view of the mires is eliminated. The graduations indicating the position of the principal meridian are on a supplementary arc, which enables the operator to read off the meridian from the position last assumed in the test, instead of being obliged to note the meridians during the examination of the cornea.

Test for Determining the Presence of Astigmatism by the Prisoptometer. The prisoptometer (Fig. 80) consists of a double prism set in a semi-circular disc, which is spaced off by meridians ten degrees apart. It is supported on a standard which is clamped to the table. The double prism has the effect of doubling the image of the object looked at. The white disc (page 95) on a dark background seen at sixteen feet by the emmetropic eye through the double prism is doubled and the images are tangent throughout all the meridians as the prism is rotated. In the ametropic eye the images are not tangent, but they overlap or separate according to the form of ametropia (myopia or hyperopia).

In examining for astigmatism, place the patient behind the prisoptometer sixteen feet from the disc. Revolve the prism and notice by the pointer on the instrument at which meridian the false image is tangent to the other. Then turn the prism around one way or the other, and if there is astigmatism, the false image, in shifting its position, will either overlap the other or separate from it, according to whether it is myopic or hyperopic astigmatism, the pointer indicating the meridian. This is a ready means of detecting astigmatism, and the amount can be ascertained by placing a lens in the clip in front of the dial of the instrument. If it is a case of myopic astigmatism, the concave glass that will distance the two images so as to make them tangent will indicate the amount of astigmatism and the glass to be prescribed. If it is a case of hyperopic astigmatism, the strongest convex glass that will approximate the two images so

as to render them tangent will show the amount of hyperopia.

Care must be taken that the eye being examined look directly through the prism and that the head be steadied; also that the disc looked at be parallel with the dial and directly in front of and of the same height as the prism, and exactly sixteen feet away. If the distance be more than sixteen feet, an emmetropic eye appears hyperopic and a myopic eye might appear emmetropic. If the disc stands obliquely to the instrument, astigmatism is falsely indicated. A spherical glass can be used for ascertaining the amount of astigmatism and a corresponding number in a cylinder must be prescribed with the axis in the meridian of emmetropia.

TEST BY THE KERATOSCOPE. The keratoscope (Fig. 79) consists of concentric rings on a disc with an opening through the center. This instrument was the foreshadowing of the Javal & Schiœtz ophthalmomètre and is an objective test based upon scientific principles. Place the patient with his back to the window, or to an artificial light, and then, with the disc in front of your eye, view the cornea of the patient's through the opening from a distance of about one foot. A magnifying glass placed back of the disc may or may not be employed. If used, it magnifies and sharpens the image. The concentric rings of the disc will be mirrored upon the cornea, and will, of course, appear very much smaller on the cornea than they are on the disc. If they are circular, no astigmatism is indicated; but if they are oval, astigmatism of the cornea is present, and the

longest diameter will indicate the meridian of astigmatism. However, great care must be taken in employing this test, for if the opening of the disc is not of the same height as the pupil and the disc parallel with the plane of the iris, the rings may appear oval, thus simulating astigmatism; or, if the opening in the disc is not perfectly circular, this would also give rise to false impressions.

TEST BY THE CHROMOSCOPE. The chromoscope (Fig. 121) consists of a card two feet square with a dial or face spaced off into merid-

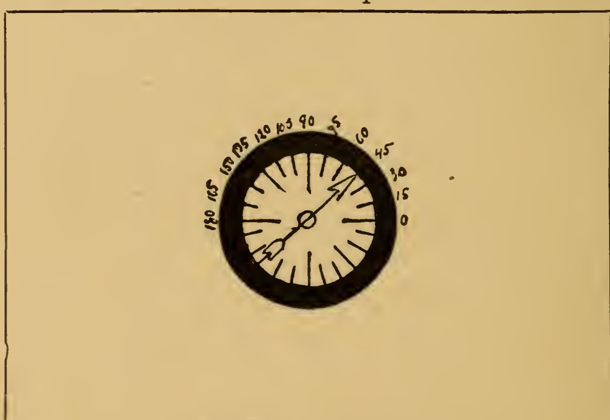
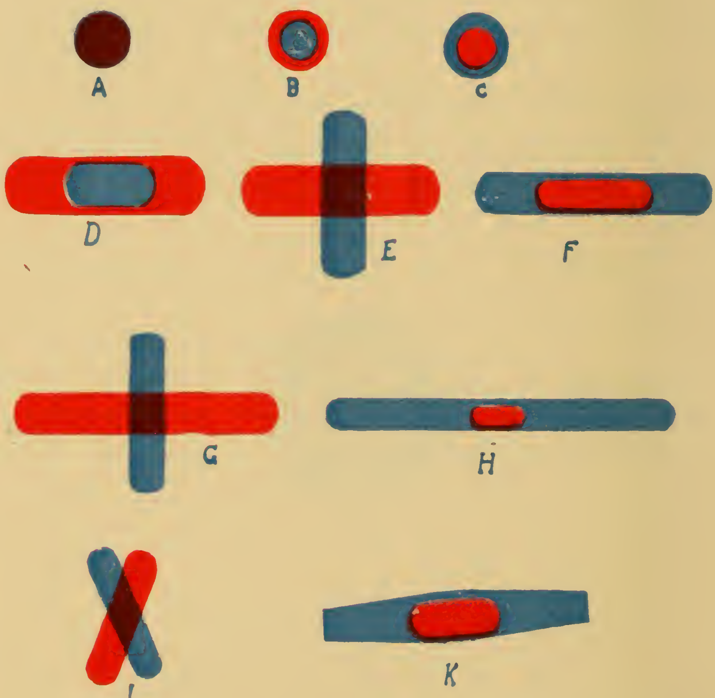


Fig. 121.—Chromoscope.

ians. In the center of the dial is a circular opening three-eighths of an inch in diameter, also a rotating ring having an indicator through its diameter extending across the circular opening. This indicator turns with the ring.

In examining with this instrument, place the patient at a distance of twenty feet, covering the eye not to be tested with an opaque disc. Then place the chromatic glass (Fig. 122) in front of the eye being tested. If the light through the

PLATE VIII.



opening appears circular, no astigmatism is indicated; but if it is elongated, astigmatism is present. In emmetropia the circle will be of a diffuse violet tint (A, Plate VIII); in hyperopia it will have a blue center and a red border (B); and in myopia the center will appear red and the border blue (C).

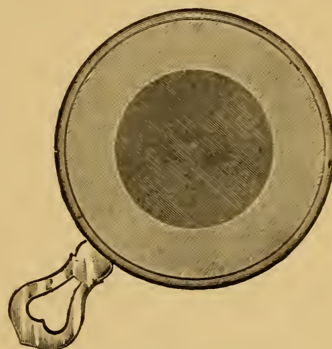


Fig. 122.

In simple hyperopic astigmatism, the circle is elongated, having a blue center and red extremities (D) or a crossed figure, the blue extending out from each side (E). Rotate the indicator to the longest axis of the figure, and read off from the dial the meridian of astigmatism. The strongest convex cylinder that will render the figure circular gives the amount of astigmatism. In simple myopic astigmatism the elongated figure has a red center with blue extremities (F); the longest axis indicates the meridian of astigmatism.

G shows the appearance in mixed astigmatism, where the degree of hyperopia is greater than the myopia; the red is longer and narrower, while the blue part crossing it is shorter. The direction of the red bar indicates the meridian of hyperopia, and the blue the meridian of the myopia. Where myopia predominates, H shows the appearance. It is an elongated, narrow blue bar with a red center. The longest axis of the bar indicates the meridian of the myopia.

In irregular astigmatism the cross is not right-angular, being in some cases a Maltese cross (I), or the bar is not of the same width throughout (K). If the myopia predominates, there is only a bar; if the hyperopia predominates, there is a cross.

Astigmatism as Detected by the Ophthalmoscope. The ophthalmoscope, as in the simple forms of ametropia, is one of the readiest and most reliable means of detecting astigmatism. By the direct method, where the eye is viewed from a distance of twelve or fourteen inches, the retinal vessels appear more distinct in a certain meridian than they do in the opposite one, and the latter is the meridian of astigmatism. If the eye is viewed from a near point, say an inch or two away, the optic disc will be seen of an oval form; and the higher the degree of astigmatism the more will the disc appear elongated. The blood-vessels in the longer diameter are more distinct than those at right angles; and if it is a case of simple hyperopic astigmatism, the strongest convex glass that will bring the blood-vessels distinctly into view will indicate the amount of astigmatism; or, if it is a case of simple myopic astigmatism, the weakest concave glass that will bring them into view will indicate the amount. If it is a case of compound astigmatism, glasses of different strengths must be used in the principal meridians. If it is mixed astigmatism, say hyperopia of the vertical and myopia of the horizontal, then the strongest plus glass that will bring the vessels distinctly into view in the vertical,

PLATE IX.

and the weakest minus glass that will bring them into view in the horizontal, will show the amount of each kind of astigmatism. If the eye is examined by the indirect method, the image of the myopic eye is always reduced.

SKIASCOPY, RETINOSCOPY (page 118). This is a ready and reliable test, and for children it is one of the most satisfactory, convenient, and speedy means. The pupil should be dilated, and the patient placed in a dark room with the light immediately above his head. With a flat mirror, at a distance of three feet, the examiner reflects the light into the pupil (Plate IX). If it is simple hyperopia, the shadow will travel in the same direction that the mirror is tilted; if it is simple myopia, it will travel in the opposite direction. In simple astigmatism the shadow will be seen only in the meridian of ametropia; if it is compound astigmatism, the shadow will be sharper in one principal meridian than in the other. If the astigmatism is in a meridian other than the vertical or the horizontal, the shadow will appear in this meridian, and although the light be thrown from above downward, the shadow, instead of traveling from above downward, may go in an oblique direction.

If it is a case of mixed astigmatism, the shadow will go *with* the mirror in one meridian, and *against* it in the other.

The lens that will neutralize or dispel these shadows indicates the amount of astigmatism, and the glass to be prescribed. (See page 124, Chap. VI.)

TEST BY TRIAL GLASSES FROM TRIAL BOX. Although we may employ these other different tests, we never feel quite warranted in prescribing glasses without making a corroborative test by means of the trial glasses from the case—the test generally used.

Examination by this method is conducted in the following manner: The patient is placed in front of Snellen's card at a distance of twenty feet. Adjust the trial frames and see that they are properly poised so that the patient will look through the center of each opening. Cover one eye, say the left first, with an opaque disc, and get the vision of the right, recording the same.

If the patient is able to see only the larger letters, or part way down the card, try both plus and minus spherical glasses. If the spherical glass does not give perfect vision, nor improve it, astigmatism may be suspected. Place a *stenopaic disc* with a narrow slot in front of the eye, and rotate the slot through the different meridians, finding the meridian of the best vision. If the meridian is found through which vision is $\frac{20}{20}$, or normal, and no glass improves, we have a case of simple astigmatism. If the stenopaic disc is now rotated to the opposite meridian, vision may be much below the normal. If so, find the strongest convex spherical or the weakest concave spherical glass that will give the greatest amount of vision in this meridian. If a convex glass improves the vision, we have simple hyperopic astigmatism. If a concave improves, it is simple myopic astigmatism. (Right here

let us observe that in spasm of accommodation, simulating myopia, slight concave glasses will improve vision, whereas hyperopia really exists. In these low forms of astigmatism, it is absolutely necessary that a mydriatic be employed, lest the real, true condition be over-looked and a false glass prescribed.)

In case that no meridian is found where vision is $\frac{20}{20}$, we may suspect either compound or mixed astigmatism. In such a case we rotate the slot to the meridian of best vision, and find the plus or minus glass that gives the greatest amount of improvement in that meridian. Then rotate the slot to the opposite meridian and find the plus or minus glass that gives the greatest amount of vision in this meridian. If a convex glass improves in both meridians, it is compound hyperopic astigmatism; but if a concave of considerable strength is required, it is a case of compound myopic astigmatism. If one meridian is improved by a convex glass and the other by a concave, this is mixed astigmatism.

PROGNOSIS.

Astigmatism, like other forms of ametropia, can be corrected by the use of glasses, but can not be cured. Frequently proper glasses adjusted in a case where the vision is so low as scarcely to enable the person to get about, give most happy results, and it is very gratifying to see the expressions of surprise and delight come over the faces of these persons as a new world is opened to them by the correction of their anomaly.

By the correction of astigmatism, the eye

grows stronger and the vision becomes more acute. Not infrequently is it impossible to find a glass that will give an approach to perfect vision; but if the glass that affords the most improvement is worn for a time, the eye will so improve that at a subsequent time a glass may be found that will give still better vision, even $\frac{20}{20}$, or the normal.

TREATMENT.

Until very recent times, it has been the custom of ophthalmologists to ignore the lower forms or a slight amount of astigmatism, correcting only the myopia or the hyperopia, but not always with the relief and satisfaction desired. It is now found that the slightest amount of astigmatism is often responsible for the most serious affections. Frequently, this slight amount of astigmatism is so concealed by the power of accommodation that it is overlooked, and it is only with the most careful and searching examination that it is revealed.

HYPOTHETICAL CASES. *First.*—Let us imagine a case of simple hyperopic astigmatism where the vertical meridian is emmetropic; *i. e.*, the patient, when the slot is rotated into this meridian, is able to see $\frac{20}{20}$; but when it is rotated into the horizontal meridian he only gets $\frac{20}{80}$, and requires a convex glass of 2.50 D. to bring the vision to $\frac{20}{20}$. This is simple hyperopic astigmatism of 2.50 D. in the horizontal meridian. To correct this, we prescribe a convex cylinder of 2.50 D., axis in the 90th meridian.

Second.—Let this be a case of simple myopic astigmatism, where, for instance, if the disc is

rotated into the 180th meridian, the vision is $\frac{20}{20}$; but in the 90th meridian vision is $\frac{20}{100}$, and requires a minus 3.50 D. to bring it to $\frac{20}{20}$. We have here a case of simple myopic astigmatism of 3.50 D. in the 90th meridian. To correct this, we prescribe a concave cylinder of 3.50 D. with axis placed in the 180th meridian.

Third.—Let this be a case of compound hyperopic astigmatism, where we find that in rotating the slot the vision is best in the 75th meridian, and a convex glass of 2 D. is required to gain the highest amount. Now, if the slot is rotated into the opposite meridian, the 165th, it requires a convex glass of 3.50 D. to get the greatest amount of vision. We have here a case of hyperopia of 2 D. with hyperopic astigmatism of 1.50 D. in the 165th meridian. In this case we prescribe a convex spherical glass of 2 D., which corrects the hyperopia, and a convex cylinder of 1.50 D., axis of cylinder in the 75th meridian.

Fourth.—Compound myopic astigmatism. In this case we will imagine the greatest amount of vision to be in the 15th meridian, but it requires a concave glass of 2 D. to give the best vision. Now, if the slot is rotated to the opposite meridian, the 105th, we find that a concave glass of 5.50 D. is required. We have here a case of myopia of 2 D. and myopic astigmatism of 3.50 D. in the 105th meridian. To correct this, we prescribe a concave spherical glass of 2 D. combined with a concave cylinder of 3.50 D., axis of cylinder in the 15th meridian.

Fifth.—Mixed astigmatism with hyperopia pre-

dominating. Here we find, for instance, that the vertical meridian requires a convex glass of 3 D and the horizontal requires a concave glass of 1.75 D. This is, then, a case of hyperopia of 3 D. in the 90th meridian, and myopia of 1.75 D. in the 180th meridian. To correct this, we may prescribe a double cylinder or a sphero-cylinder. If two cylinders are used, the prescription should call for a convex cylinder of 3 D., axis in the 180th meridian, combined with a concave cylinder of 1.75 D., axis in the 90th meridian.

If a sphero-cylinder is employed, the anomaly may be corrected by using a spherical convex glass of 3 D. This corrects the hyperopia, but increases the myopia to 4.75 D., and hence the plus 3 D. spherical must be combined with a minus cylinder of 4.75 D. with its axis in the 90th meridian.

It can also be corrected by using a concave spherical glass of 1.75 D. combined with a convex cylinder of 4.75 D., axis in the 180th meridian, for in using the minus spherical glass of 1.75 D. we have increased the hyperopia to 4.75 D.; therefore, the convex cylinder must be of this strength.

Sixth.—Mixed astigmatism with myopia predominating. We will imagine this to be a case where, if the slot is rotated to the 60th meridian, vision is $\frac{20}{80}$, and requires a convex glass of 1.75 D. to gain the highest amount of vision; and if the slot is rotated into the opposite, or 150th meridian, vision is $\frac{20}{100}$ and requires a concave glass of 4.25 D. We have here, then, a case of

mixed astigmatism with myopia predominating. To correct this we may use a double cylinder or a sphero-cylinder, preferably the latter. Of the sphero-cylinder, either a convex spherical glass with a concave cylinder, or *vice versa*, may be employed. Hence we prescribe either a concave spherical glass of 4.25 D. combined with a convex cylinder of 6.00 D., axis in the 150th meridian; or a convex spherical of 1.75 D. combined with a concave cylinder of 6.00 D., axis in the 60th meridian.

If the double cylinder is used, we employ a convex cylinder of 1.75 D., axis in the 150th meridian, combined with a concave cylinder of 4.25 D., axis in the 60th meridian. You notice here that the axis of the cylinder is always placed in the meridian which we do not wish to affect by the glass.

Astigmatism is frequently concealed by the power of accommodation, especially in the low degrees. In these individual cases, as before said, complete mydriasis is imperative that the true conditions be revealed; and it is these special cases which are so troublesome, the treatment oftentimes being unsatisfactory, giving little or no permanent relief, the asthenopia persisting. Especially are these low forms of astigmatism associated with heterophoria, the insufficiency of the extrinsic ocular muscles being as responsible for the persistent asthenopia as the errors of refraction. In treatment the entire amount of astigmatism should be corrected and no deduction made.

In prescribing glasses for mixed astigmatism, the bi-cylinders give a broader and flatter field;

and in a high degree this form of glass is considered preferable to the sphero-cylinder. I have found in some cases of *mixed* astigmatism especially in the young, that if I corrected both meridians, the glasses were not worn with comfort and satisfaction, but if two pairs were prescribed—simple cylinders—these were accepted with perfect satisfaction; for instance, imagine a case of mixed astigmatism of hyperopia of 2 D. in the 180th meridian, and myopia of 3 D. in the 90th meridian. Instead of correcting both with one glass, I correct the hyperopia with a simple plus cylinder with axis in the 90th meridian, and the myopia with a minus cylinder, axis in the 180th meridian, directing the patient to use the former for near and the latter for distant objects.

In case of simple myopic astigmatism, after the appearance of presbyopia, instead of using a convex spherical and a concave cylindrical glass, a convex cylinder only may be prescribed; as, for instance, if we have myopia of 1.50 D. in the 180th meridian, and presbyopia of 1.50 D., we may simply correct the anomaly by a plus cylinder of 1.50 D. with the axis in the 180th meridian. The cylinder corrects the presbyopia in the 90th meridian, and the opposite meridian, previously myopic, is now from the presbyopia emmetropic; that is, for near objects.

Frequently, we find before the use of a mydriatic that the patient will accept a minus cylinder varying in amount from 0.25 D. to 1 D. in the 180th meridian., but after the use of the myd-

riatic, this concave glass will no longer improve vision, but a convex cylinder in the 90th meridian improves. The latter glass reveals the real anomaly—simple hyperopic astigmatism. In such a case, the use of the mydriatic has to be continued for some time to overcome the spasm; for if not, as soon as the effect of the mydriatic passes away, the apparent myopic astigmatism will reassert itself. Occasionally, in anisometropia, it is found best to correct the eye requiring the weakest glass, and then a portion of the ametropia of the other eye by a glass of the same strength, rather than to correct the full amount of each. The former are usually worn with much more comfort and satisfaction than the latter. In astigmatism, it is especially

Fig. 123.

essential that the glasses be properly set, that the axis of the cylinder be in the meridian prescribed, and that the glasses be so poised as not to allow tilting or riding obliquely on the nose, and in order to secure this, it is best to have them mounted in spectacle frames rather than in a

Fig. 124.

pince-nez. If a pinch-nose is used, the bar frame should be employed (Fig. 123) instead of the ordinary spring (Fig. 124). The glasses should be carefully centered as to the pupils (Fig. 125). They should be on a plane parallel to that of the irides, and not

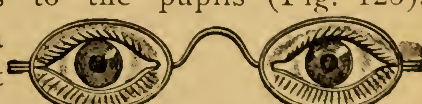


Fig. 125.

too far from the eyes. If they are convex and too far, the strength is increased; if they are concave, it is diminished. Neither should they be set too close to the eyes, lest they touch the lashes.

In the treatment of astigmatism, some form of cylindrical glasses (Fig. 126) must be used. These glasses are not kept in stock by spectacle dealers, but have to be ground and the axis of the cylinder set in the special meridian for each individual case.

Fig. 126.

At first, cylindrical glasses were ground by hand to meet the demand for each individual case, and, of course, were very expensive; but more recently, to meet the great demand for these glasses, machinery has been constructed for grinding the different forms of cylinders with perfect accuracy and cheapness, so that the objection—expense—in procuring these glasses is largely done away with, and the low forms of astigmatism, which are so provocative of asthenopia, are now corrected, whereas in former days they were ignored, and the patient allowed to suffer.

Cylindrical glasses are in reality sections of cylinders instead of spheres, the section being on a plane parallel to the axis of the cylinder. Rays of light passing through such a glass are refracted only in a plane at right angles to the axis of the cylinder; those passing through the axis are

not changed in their course. Hence, these glasses, instead of bringing the rays of light to one point as spherical glasses do, refract the rays

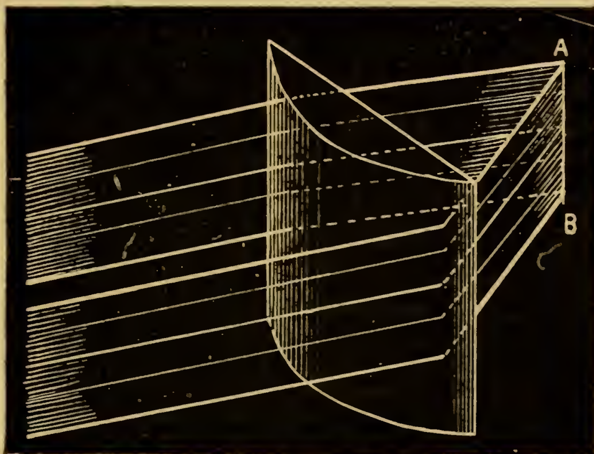


Fig. 127.

only in one axis, forming a line instead of a point (AB, Fig. 127).

The most common forms of cylindrical glasses are the plano-cylindrical convex (A, Fig. 128),

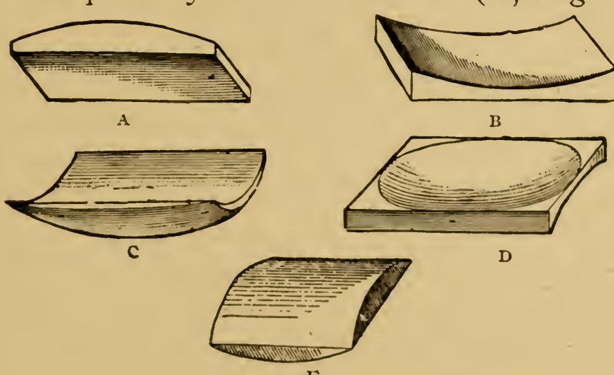


Fig. 128.

plano-cylindrical concave (B), sphero-cylindrical convex (C), sphero-cylindrical concave (D), and

crossed cylindrical glasses (E). These latter are formed of two plano-cylindrical glasses, the plane surfaces placed together with their axes at right angles to each other.

TORICAL GLASSES. A torical glass (Latin, *torus*, a tore) is one in which one of the surfaces is a segment of an equatorial zone of a tore.

A tore is a large ring used at the base of a column, and whose profile is semi-circular. An ordinary rubber ring, such as is given teething children to play with, will represent a tore. If a slice be cut off from the outside of the ring, as indicated by the line AB (Fig. 129), the convex surface of this represents a convex torical glass. A depression into which this surface will exactly fit represents the surface of a concave torical glass. Thus, a plano-torical glass has a plane surface, and the other may be convex or concave, but the two principal meridians differ in their refractive power. A glass, then, with one surface torical convex and the other plane, acts as a convex glass in the two meridians, but stronger in one than in the other, the total effect being equal to a convex cylinder combined with a convex spherical. The advantage over the cylindrical is that they are more periscopic. Suscipe, an optician of Rome, was, perhaps, the first to correct astigmatism by means of the torical glass.

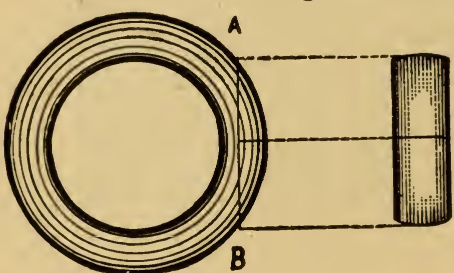


Fig. 129.

With this glass, the field of vision is supposed to be greater and flatter than with the sphero-cylindrical.

HYPERBOLICAL GLASSES. In cases of irregular astigmatism with slight conicity of the cornea (*keratoconus*), where the curvature is greater in the center than towards the border, M. Raehlmann has attempted to correct this anomaly by a hyperboloidical glass, but the results obtained have not been very satisfactory, because of the irregularity of the form of the cornea and the great difficulty which presents itself in the construction of the glass. For this condition of the eye M. de Wecker has constructed a similar glass with the concavity increasing on approaching the center. This, too, as yet, is of little practical use.

CHAPTER X.

ANISOMETROPIA, APHAKIA, AND PRESBYOPIA.

ANISOMETROPIA.

Anisometropia (ἄνισος, unequal; μέτρον, measure; and ὄψις, vision) is that state in which the refraction of the two eyes is unequal, they requiring glasses of different strength. Any two of the several forms of ametropia may exist in the same individual. One eye may be emmetropic, the other myopic or hyperopic; both may be hyperopic or myopic, but of a different degree; one may be hyperopic, while the other is myopic; one may be astigmatic, while the other is emmetropic, myopic, or hyperopic; again, both may be astigmatic, but differing in kind or degree.

Anisometropia is either congenital or acquired. In the majority of cases it is congenital. Acquired anisometropia is most frequently brought about by extraction of the crystalline lens for cataract. Where it is congenital it is attributable to the unequal development of the eyes, and may be associated with a simple inequality of the development of the corresponding orbits as well as the two halves of the brain. It is frequently associated with asymmetry of the face and cranium, yet there may be a marked asymmetry of the two sides of the face without any anisometropia. The development of the cranium as to its length

and width influences the development of the shape of the eyeballs.

In anisometropia concurrent with asymmetry of the face, Donders has shown that the eye with the strongest error of refraction is nearer the median line.

In anisometropia sometimes both eyes fix simultaneously, and binocular vision exists. More frequently, especially if there is a marked difference in the refraction of the two eyes, the anisometrope uses each eye alternately. In others, fixation is limited to one eye, the other being allowed to go at will.

In almost every case of error of refraction there is a certain amount of anisometropia—in appearance, if not in reality; but what appears to be anisometropia is often due to a difference in the power of accommodation, and not to refraction; and when the power of accommodation is completely set aside, the vision of both eyes is identical, and the error of the two eyes can be corrected by the same kind and strength of glass.

TREATMENT.

If one eye is emmetropic and the other ametropic, it is not advisable, as a rule, to encumber the patient with glasses for the sake of trying to correct the ametropic eye; for although the ametropia may be perfectly corrected, yet this eye with the glass and the emmetropic eye will not work well together.

In case of one myopic eye and one hyperopic, it is advisable to select the eye with which the

patient can work best, correct with a glass the anomaly, and therewith rest content.

It may be well to advise him, however, of man's infinite power to adapt himself to circumstances, and suggest that he learn to use the myopic eye for near and the hyperopic for distant objects. Occasionally, satisfactory results may be gained by correcting the anomaly of each eye, giving a concave glass for one and a convex for the other.

APHAKIA.

Aphakia (ἀ, without; and φακός, lens) is that condition of the eye when deprived of its crystalline lens.

The crystalline lens, *in situ*, has the optical action equal to that of a convex lens of 11 D. placed in front of the cornea.

The emmetropic eye deprived of its crystalline lens becomes hyperopic to the amount of 11 D. If the eye was previously hyperopic, then its hyperopia would be increased 11 D.; for example, if the eye was previously hyperopic of 2 D., deprived of its lens it would become hyperopic of 13 D.

If the eye was previously myopic to the amount of 11 D., deprived of its lens it would become, theoretically, emmetropic.

If the myopia is less than 11 D., then the eye would be hyperopic to the amount of the difference between 11 D. and its myopia.

If it is more than 11 D., it would be still myopic to the amount of the difference between the myopia and 11 D.

Example: If the myopia is 5 D., the amount

of hyperopia would be 6 D.; if the eye was myopic of 12 D., then, theoretically, it would have 1 D. of myopia.

The condition of aphakia may be recognized by the following symptoms: Increased depth of the anterior chamber with a flattened, tremulous iris, and absence of the crystalline reflex in the "catoptric test."

In aphakia the dioptric system of the eye is reduced to its simplest form, having the refraction of the cornea, aqueous, and vitreous; the two latter, being of the same index of refraction, may be considered as one single medium. The nodal point of the aphakic eye corresponds with the center of the curvature of its cornea, and advances when corrected by a strong convex glass placed at a certain distance from the cornea; and therefore this eye receives a large retinal image.

The aphakic eye is not only deprived of a considerable amount of its static refraction, but also of its entire dynamic refraction. The power of accommodation being gone, two pairs of glasses are necessary, one for near and the other for distant objects; the stronger for divergent and the weaker for parallel rays. This want of accommodation could be partially supplied by changing the position of the glasses with respect to the distance from the eye; for the further away the convex glass is from the eye (within a certain limit) the greater is the amplification; the hand in this instance takes the place of the ciliary muscle. However, this is only practicable for limited distances, two pairs of glasses being absolutely

necessary, unless it be where the eye approaches the emmetropic condition from its previously high degree of myopia.

In the majority of cases of aphakic eyes from extraction or absorption of the crystalline lens, the glass required for distant objects is about + 9 D., and that for near + 11 D. In the use of these strong glasses, a slight variation as to position and distance from the eye produces a decided change in the refraction. If the glasses are tilted from the plane parallel to the iris, they produce an effect of astigmatism; and if they are not correctly centered, they will cause very great inconvenience in the way of diplopia or displacement of the object looked at. Astigmatism sometimes appears after the extraction of the lens, and if it is of slight amount, the tilting of the spherical glass may suffice, correcting the astigmatism without the use of cylinders; but if it is of any considerable amount, the astigmatism with the hyperopia should be corrected by a sphero-cylindrical glass. Unless the glasses are properly centered, they act as prisms and displace the image, giving a false impression as to height or position; as the floor or steps, making it difficult for the aphakic person to get on or off the cars, or climb stairs. This is sometimes true even where the glasses are carefully centered, and then can be corrected by a periscopic glass, or the combination of prisms.

PRESBYOPIA.

As we have already seen, the emmetropic eye is not adjusted for near and distant objects at one and the same time. It is constantly chang-

ing in its refraction when viewing objects at an infinite distance and when looking at them from a finite distance; in other words, the emmetropic eye, in its passive condition, is adjusted only for parallel rays and has to accommodate itself for divergent. This adjustment is brought about by the action of the power of accommodation, which power is lodged in the ciliary muscle. This power, in the emmetropic eye, is adequate to meet the demands for about forty or forty-five years, when it begins to wane and refuses longer to supply this demand, and assistance has to be rendered by the use of convex glasses.

From the fact that this power of accommodation does not give way until later on in life, and vision by the diminution of the power of accommodation is then affected, this condition is called *presbyopia* (*πρέσβυς*, old; and *ὄψις*, vision). It is a tired and exhausted condition of the ciliary muscle. This little muscle, which has been constantly brought into requisition whenever the person wished to look from a distant to a near object, lasts for forty or more years, but finally it gives way completely and refuses longer to perform its function. One, knowing the etymology of the word, *presbyopia*, is reluctant to acknowledge this defect, evidencing, as it does, old age creeping on. However, this is only true in a limited sense, for the hyperope may be presbyopic, even at an early age, while the myope is not presbyopic until late in life, or, perhaps, never becomes so. Presbyopia, then, is a faulty condition of the static refraction, demanding relief or

assistance by the use of a convex glass. At first the accommodation only partially gives way, and the ciliary muscle asserts its right and refuses to be aided except by a weak glass, not tolerating a strong one; however, as time advances, the muscle becomes more inert and the weak glass has to give place to a stronger, until finally the muscle ceases almost entirely to act, and a strong convex glass is demanded. If there is hyperopia with presbyopia, the glass, of necessity, to correct this condition has to be sufficiently strong to correct not only the hyperopia, but also the presbyopia.

Here, again, glasses of different strength have to be used, a weaker for the hyperopia or for distant objects, and a stronger for near objects.

The popular idea of deferring the use of glasses when presbyopia exists is frequently provocative of more serious conditions. As soon as the ciliary muscle shows evidence of inability to perform its function, it should be aided by the proper convex glass. Care, however, should be taken not to give too strong a glass at first. In the beginning of presbyopia the person first notices the failure of vision when using artificial light, as from a lamp; for although he is able to read, perhaps, the finest print by daylight, he has to hold the print at a further distance at night, and even then the page may be more blurred and the letters indistinct.

This is one of the first symptoms of presbyopia, this desire to get the book or work at a greater distance from the eye than has been the habit heretofore, since the further away the object,

the more the rays of light from it approach the condition of parallelism, and the less is the demand upon the power of accommodation.

In the emmetropic eye with presbyopia the near point is further removed, but the far point remains at the normal distance; therefore, glasses are only required for near objects; however, this recession of the near point from its normal position begins really in very early life, about the age of ten years, and progresses gradually with increasing years. At forty it lies at eight inches, and at fifty at eleven or twelve inches. In the emmetrope no inconvenience is experienced before the age of forty or forty-five years. This change in the position of the near point is met with in all eyes, whether they are emmetropic, hyperopic, or myopic. In the emmetropic at fifty there is a slight amount of hyperopia, and at seventy or eighty years the hyperopia equals at least 0.50 D., and that has to be added to the presbyopia.

An eye is considered to be presbyopic when the near point has receded further than eight inches from the eye. The patient then complains of work at a near point becoming irksome and fatiguing, and asthenopic symptoms appear with amblyopia. Although most emmetropic eyes become presbyopic at the age of forty or forty-five, there are exceptions where presbyopia comes on at a much later period in life. Prof. Sichel, of Paris, called my attention to the fact that he had then, at the age of fifty-five, perfect power of accommodation, or the absence of presbyopia. He

was able to read the finest print at the normal near point, and yet had perfect vision for distant objects.

Besides the diminished power of the ciliary muscle, the consistency of the lens comes in as a factor in presbyopia. The lens, as is well known, grows harder from childhood to old age, the hardness beginning in the nucleus, and the lens loses its elasticity. Presbyopia, then, is due to both lack of power of the ciliary muscle and diminished elasticity of the lens.

At first it suffices to prescribe glasses for night work or for artificial light, allowing the presbyope to use his power of accommodation by daylight, but after a time it will become necessary for him to use a glass at all times when viewing near objects. The weakest plus glass that will enable the presbyope to read the fine print, No. 1, according to Jaeger, at fourteen inches, indicates the glass to be prescribed.

Each eye should, as in other anomalies, be tested separately; however, it is always best to give the same strength of glass to each eye, especially if the difference is only slight; frequently this difference is dynamic and not static. Correct the eye that requires the weaker glass, and give the same strength to the other eye. However, in exceptional cases of marked difference in the refraction of the two eyes, each eye should be corrected irrespective of its fellow.

Glasses should not be selected in a haphazard way by the person himself or by the untutored dealer in spectacles; more especially by *dry goods merchants* and *jewelers*.

The age of a person is not necessarily an index of the strength of glass to be prescribed, and the "Smart Aleck" who claims to be able to hand out the proper glass once knowing the age is very liable to give the wrong glass. Presbyopia with hyperopia, as we have already said, requires a much stronger glass than the same aged emmetrope with presbyopia. The myope of a slight degree with presbyopia, would not require so strong a glass as even the emmetrope, nor would a spherical glass meet the exigencies of the case when there is astigmatism combined with the presbyopia.

Especially is it necessary that the person beginning the use of glasses have his eyes carefully tested by a skilled oculist, and start out with the proper glass to meet the exigencies of the case.

CHAPTER XI.

HETEROPHORIA.

INSUFFICIENCY OF THE OCULAR MUSCLES.

Heterophoria (ἕτερος, other; and φορεῖν, to bear) is the term employed to signify that condition of the eyes where there is a want of balance of the extrinsic ocular muscles due to insufficiency or paresis of these muscles.

Orthophoria (ὀρθός, right) is the term used to signify that condition of the eyes where there is perfect balance and co-ordination of the extrinsic ocular muscles.

According to Dr. Stevens, *orthophoria* denotes parallelism of the visual lines, or normal power of the muscles.

Heterophoria, non-parallelism of the visual lines; or muscular insufficiency.

Esophoria (ἔσω, within), a convergence of the visual lines; or insufficiency of the abductors.

Exophoria (ἔξω, without), divergence of the visual lines; or insufficiency of the adductors.

Hyperphoria (ὑπέρ, over) is the term used to indicate that the visual line of one eye is above that of its fellow; or insufficiency of the inferior rectus.

Cataphoria (κατά, down) is the term used to indicate that the visual line of one eye is below that of its fellow; or insufficiency of the superior rectus.

Hyper-esophoria signifies a tending of the visual line upward and inward; or insufficiency of the inferior and external recti.

Hyper-exophoria, a tending upward and outward; or insufficiency of the inferior and internal recti.

Eso-cataphoria, inward and downward; or insufficiency of the external and superior recti.

Exo-cataphoria, outward and downward; or insufficiency of the internal and superior recti.

In the four latter forms, the oblique muscles are frequently at fault.

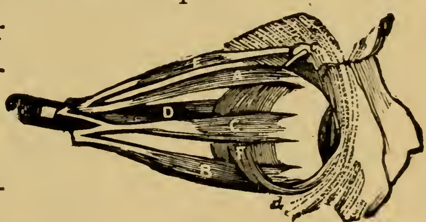


Fig. 130.

That we may better understand and appreciate the anomalies and insufficiencies of the ocular muscles, let us briefly consider these muscles from an anatomical and physiological standpoint.

EXTRINSIC MUSCLES OF THE EYE. Each eye has six muscles, four recti (A, B, C, and D, Fig. 130) and two oblique (E and F).

The model (Fig. 131) also represents them.

The recti originate from the apex of the orbit at or near the margin of the optic foramen, and surround the optic nerve as it passes into the orbit (Fig. 132). They extend forward and are inserted into the sclera by their tendinous extremities at about six or seven millimeters back of the limbus. The superior oblique (E) also has its origin at the apex of the orbit, but its functional attachment is at the anterior, superior, and internal

portion of the orbit, where it passes over a pulley (*c*, Figs. 130 and 132).

The external rectus (C) has its attachment a little further back on the sclera than the internal (D). The superior oblique (E) wraps around the upper part of the globe, passing under the superior rectus, and is inserted into the sclera at its outer side just back of the equator of the eye.

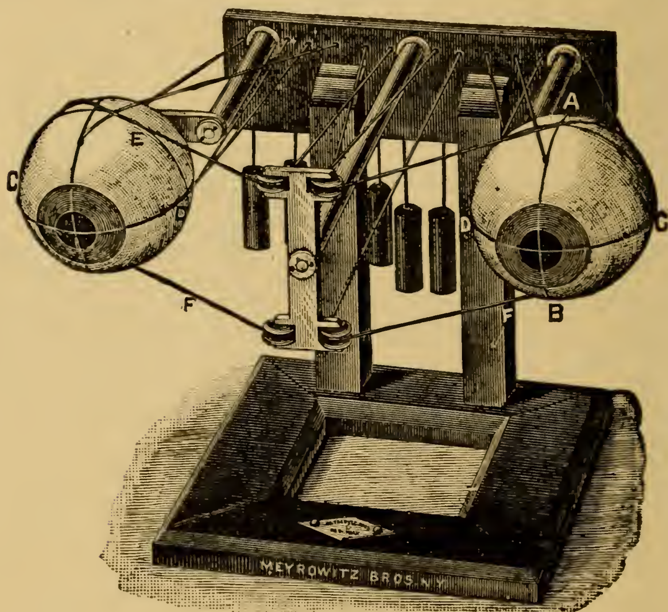


Fig. 131.

The inferior oblique (F) takes its origin from the anterior and inferior portion of the orbit, wraps around the lower portion, going beneath the inferior rectus, and is inserted into the sclera near the insertion of the superior oblique.

The combined action of the recti is to retract the globe into the orbit, while that of the oblique is to advance it and also slightly turn the cornea out-

ward. The superior and inferior recti rotate the ball on a vertical plane, while the external and internal recti rotate it on a plane transverse to the vertical, but with the outer pole of its axis further back than the inner because of the external rectus being inserted further back than the internal.

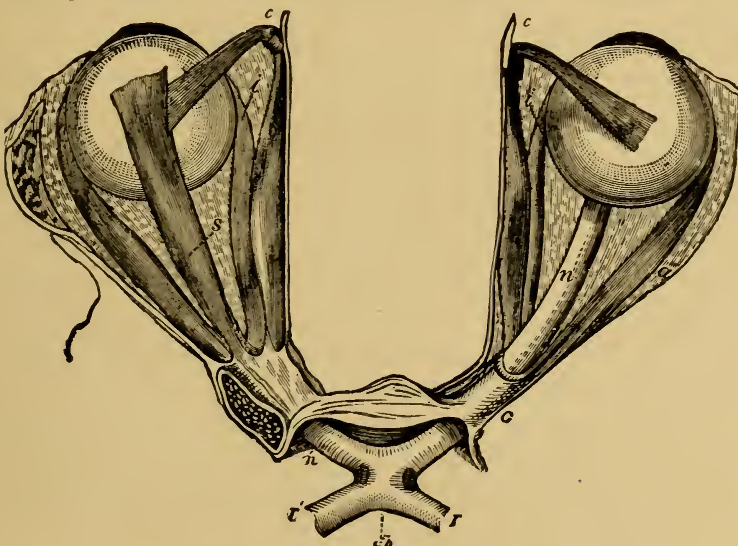


Fig. 132.

The individual action of the muscles is as follows: The superior rectus (A, Figs. 130 and 131) rotates the eye upward and slightly inward. The inferior rectus (B) rotates it downward and slightly inward. The external rectus (C) moves the eye outward and slightly upward or downward, according to the way the eye is directed. The internal rectus (D) turns the eye inward and, beyond a given point, slightly upward or downward. The superior oblique (E) rotates the eye slightly downward and outward, while the inferior oblique (F) rotates it upward and outward.

In order to have perfect balance and co-ordination, each muscle must have its quota of strength, one antagonizing or balancing the other; and when certain movements are made, one predominates over the other.

The muscles are supplied by the third, fourth, and sixth pairs of nerves. Three of the recti (superior, inferior, and internal), and the inferior oblique are supplied by the oculo-motor, or third; the superior oblique by the trochlearis, or fourth; the external rectus by the abducens, or sixth.

The *adductors* are the internal recti, assisted by the superior and inferior recti, and antagonized by the *abductors.*

The *abductors* are the external recti and the oblique, antagonized by the *adductors.*

The muscles that direct the eye upward are the superior rectus, inferior oblique, and upper fibres of the external and internal recti, antagonized by those that direct it downward.

The muscles that direct the eye downward are the inferior rectus, superior oblique, and lower fibres of the internal and external recti, antagonized by those that direct the eye upward.

In looking obliquely upward and outward, there is a combination of the superior and external recti with the inferior oblique; downward and outward, the external and inferior recti with the superior oblique; inward and upward, the superior and internal recti; downward and inward, the internal and inferior recti.

The rotary motion is effected mostly by the oblique, although the recti assist alternately.

Ordinarily, we fix our vision on near objects, thus converging the optic axes, and so bring the adductors more constantly into action. By this frequent use of the adductors a preponderance of power over the abductors is gained. In the emmetropic eye the adductors can overcome a prism of 40° or 50° with the base outward, while the abductors can only overcome a prism of 7° or 8° with base inward. In looking off at a distance, there is a demand upon the abductors.

The imaginary line drawn from the macula lutea through the nodal point to the object looked at is called the *visual line*, and the place where the visual lines of the two eyes meet is called the *point of fixation*.

HOROPTER. The *horopter* (*ὅρος*, a boundary; *ὀπτήρ*, one who sees) is that region of external space the different points of which are imaged on the maculæ or corresponding spots of the two retinæ, thus one exactly covering the other; or, in other words, it is that space within which both eyes can fix the object at one and the same time. If the face is directed toward a certain object, the two eyes may fix this object simultaneously without difficulty; also all objects, without changing the position of the face and within a certain limit, are seen simultaneously with both eyes, and binocular vision is maintained; but beyond a certain limit one eye may fix the object while the other lags, and the image of the object falls to one side of the yellow spot and diplopia—double vision—is the result. This space, then, in which any and all

objects may be fixed by both eyes simultaneously, is called the *horopter*.

The horopter varies in its scope in different individuals. In some it is much larger than in others and is greater in certain directions.

In order that binocular vision be enjoyed, both eyes must fix the object at one and the same time; that is, the image must fall upon the macula of each eye, or, if outside of the macula, the location of one must exactly correspond with that of the other. For all objects on which we do not fix the fovea are outside the line of direct vision, and for them we have diplopia; but we are not disturbed by double vision of an object upon which we are not fixing attention; we ignore such objects: as an illustration, we work with the microscope or view the fundus of the eye with the ophthalmoscope with both eyes open, ignoring the objects seen by the eye unemployed.

If there is a lack of balance of the muscles due to insufficiency, or preponderance of power on the part of one muscle or set of muscles, co-ordination is imperfect, and it is with constant effort that binocular vision is maintained. One eye deviating, the images of the objects do not impinge at corresponding places on the retinæ; therefore, one image does not exactly cover the other, but laps on to the other, or they are entirely separated, and partial or complete diplopia results; or, if binocular vision is maintained, it is with the greatest effort, taxing to the utmost the power of co-ordination, with a strained, tired feeling of the eyes resulting.

Insufficiency of these muscles may be due to enervation and is frequently found in persons of delicate health, who are weak, nervous, debilitated, and overworked. It may be as a reflex from some uterine disease or affection of any of the genital organs, disease of the rectum, of the lachrymal apparatus, hypertrophy of the turbinates, nasal polypi, enlarged tonsils, etc. It is most frequently due to some anomaly of refraction—hyperopia, myopia, or astigmatism. Very frequently it is associated with anisometropia. There should always be a certain reserve force of the muscles or static power to insure indemnity against asthenopia (weak sight). As yet, the exact amount is not determined. This insufficiency of the ocular muscles or so-called heterophoria may be due to a congenital insufficient amount of fibres in one or more of the muscles; to an abnormal attachment or position of the tendon of the muscles, either too far back or too far forward or obliquely attached; or it may be due to an abnormality as to the position of the yellow spot of one eye; or it may be due to an enervation or congenital lack of nerve supply. That it is usually dependent upon some form of ametropia is generally conceded; however, it is frequently found in a perfectly emmetropic eye. Weakness of the adductors appears with myopia and myopic astigmatism. Weakness of abductors appears with emmetropia, hyperopia, and hyperopic astigmatism.

This static or latent reserve force can be estimated by the use of prisms; as, for instance, if a weak prism is placed before one eye with base

inward (Fig. 133) and we look at an object, as a gas-jet; the jet may appear double at first and then the two jets approach each other and finally fuse. At the same time, the eye with the prism before it is seen to move outward; this turns the base of the eye inward so that the image of the jet which the prism has deflected inward may fall upon the macula lutea. By placing the prism base outward (Fig. 134), the adductors may be similarly tested. The power of abduction is much less than that of adduction; for whereas the abductors with the base of the prism turned towards the nose can only, as a rule, overcome from three to eight degrees, the

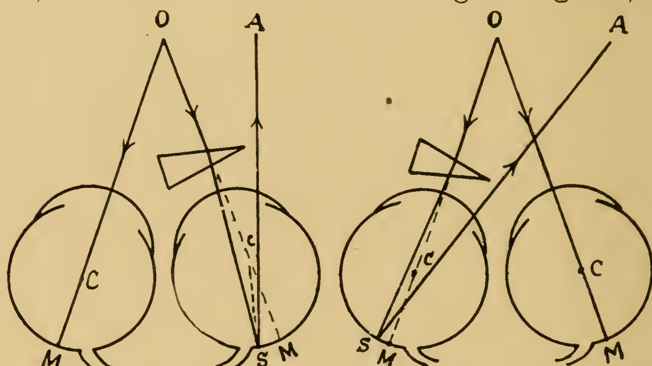


Fig. 133. Fig. 134.

O, Fixation Point; S, Impinging Point; M, Macula Lutea; C, Center of Eyeball; A, Place of Projected Image; OM, Visual Line; CS, Radius of Curvature.

adductors will overcome a prism of from thirty to fifty degrees; that is to say, with a prism of a high degree, base outward, deflecting the image towards the temple, the eye will turn sufficiently inward to throw its base outward that the image may impinge upon the macula.

As has been said, we cannot at the present time state just how much latent power is necessary to insure indemnity against the functional

muscular insufficiency called "muscular asthenopia." What would constitute a normal condition in one person might be an insufficiency in another.

Insufficiency of the externi is much more frequent than of the interni. As already said, insufficiency usually co-exists with some error of refraction. Yet not infrequently is it present in a perfectly emmetropic eye, or in eyes with very slight ametropia.

Dr. Noyes finds in one hundred cases of heterophoria, treated within two years, from 1885 to 1887:

INSUFFICIENCY OF EXTERNAL RECTUS.

Emmetropic	45
Hyperopic	9
Myopic	1
Hyperopic astigmatism	13
Myopic astigmatism	4
Mixed astigmatism	2
Total	74

People beyond the age of puberty are more susceptible to heterophoria than those under; yet many children from seven to fifteen have it, and even to that extent that requires operative procedure.

Insufficiency of the ocular muscles—heterophoria—simulates certain nervous conditions manifested in neurasthenic people with active mental faculties. Hundreds have this anomaly and do not know it. It is called "frontal" or "temporal headache." People thus affected complain of being unable to read long at a time without the

eyes tiring, aching in the depth of the eyeball, a dizziness and swimming sensation, and inability to appreciate distances. In aggravated cases the floor or ground seems uneven; climbing stairs is done with difficulty; there is vertigo, especially when looking from a great elevation. Objects may or may not appear double; if not, they may be slightly shaded or fringed at the edge; or the double images may constantly separate and approach or even fuse, and, for a time, be one.

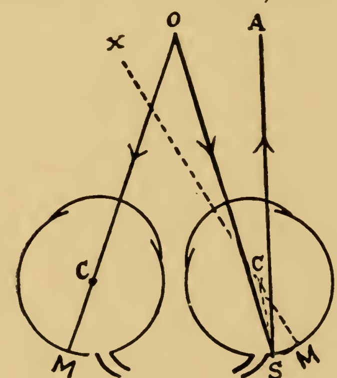


Fig. 135.

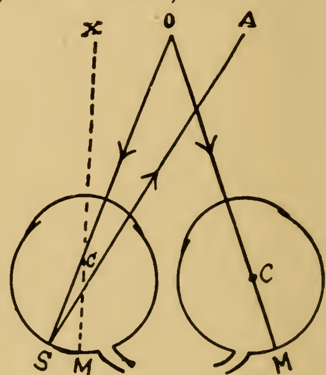


Fig. 136.

O, Fixation Point; S, Impinging Point; M, Macula Lutea; C, Center of Eyeball; A, Place of Projected Image; OM, Visual Line; XM, Optic Axis; CS, Radius of Curvature.

There is a constant effort to co-ordinate, and this effort brings on nausea (sick headache, so called) and dizziness. Life becomes a burden; despondency, melancholia, insomnia, insanity, and suicide may be the end. If the abductors are at fault, the eye turns inward, throwing the fundus outward, and the image is mirrored upon the retina inside of the yellow spot, and is projected outward (SA, Fig. 135), producing *homonymous* diplopia; that is, the left image is seen by the left eye, and the right by the right eye.

Where the adductors are at fault, the eye deviates outward and the false image is thrown across; for here, the eye turning outward, the fundus turns inward, and the image is mirrored upon the retina outside the yellow spot, and is projected across, thus giving rise to *heteronymous* or *crossed* diplopia (Fig. 136). Here the left image is seen by the right eye, and the right by the left.

In the first place we have convergence of the axes, and in the other, divergence; but it is frequently the case that the inferior or superior recti or the oblique may be at fault, and one image be directly or obliquely above the other.

Asthenopia, as we have said, may depend upon various causes. If upon refractive errors, it is then brought about by overtaxing the power of accommodation (the ciliary muscle), as well as by insufficiency of the external ocular muscles. However, as said, an emmetropic eye, with absolutely no anomaly of refraction, becomes asthenopic from neurasthenia and reflex troubles, as catarrh of the nasal and post-nasal passages; for there is an intimate connection between affections of the eye and those of the lachrymal apparatus, as well as those of the nasal passages and frontal sinuses, one depending upon or influencing the other.

All forms of uterine disease are liable to produce asthenopia. Overwork, sewing, reading, writing, engraving, or reading while lying down, or on the moving car, or carriage, may produce asthenopia. While in a recumbent position, un

less the paper or book be held directly above the face, there is a constant strain upon the inferior recti muscles, in order to turn the eyes sufficiently downward upon the page. This soon results in fatigue to these muscles. In reading in a jostling car or carriage the power of accommodation is brought into requisition, and so the ciliary muscle becomes tired and ciliary neuralgia or frontal or temporal headache results.

There is pain on using the eyes for near objects, especially in hyperopia, where the power of accommodation and the muscles of adduction are constantly called into use; for the nerves that supply the power of accommodation and that of adduction have the same origin or are intimately connected. Many people also experience much pain in looking at distant objects, as in the church or the theater. Especially is this the case when there is a slight myopia with insufficiency of the adductors, and people thus affected will complain of a blur or cloudiness or a slight halo or shade about, or at one side of the object looked at. Occasionally they will complain of double vision. It is in these cases of slight amount of error of refraction and muscular insufficiency that the symptoms are most pronounced, for the images are so near together, now blending, again separating or passing off to one side or the other, that great confusion and suffering arise with a constant strain and effort to co-ordinate. Medicines do not help; glasses do not help; rest does not help—it seems that there is no help. These

are the cases that require the most careful attention and searching examination.

The power of accommodation must be completely set aside by a strong mydriatic, repeated and continued for several days, in order that any hidden ametropia, however slight, may be revealed and corrected. Any insufficiency of the recti or oblique muscles must also be corrected. This correction is frequently brought about by enjoining rest, toning up the system, or by slight gymnastic exercise of these muscles by means of prisms. Others may require either a graduated or complete tenotomy.

These different forms of heterophoria are among the most perplexing and obstinate affections the oculist has to deal with, and unless the greatest care, patience, and skill are exercised in ferreting out the real anomalies and the exact treatment prescribed, all is to no purpose, all is confusion and no relief is given. The pain is usually referred to the ball itself, sometimes to the temples, over the brow, or to the base of the brain, and frequently ends in nausea, sick headache, and vomiting. In neurotic and feeble patients, the muscular errors or insufficiencies may produce aphonia, diarrhœa, pain of the ovaries, dizziness, St. Vitus's dance, and insanity even. Asthenopia and hysteria frequently go hand in hand. There is no doubt that epilepsy is frequently due to some insufficiency or anomaly of some of the muscles of the eye; to want of balance, especially if these insufficiencies are associated with hyperopia or astigmatism.

Dr. Stevens cites many cases of epilepsy cured by tenotomy of the recti. Dr. Ranney also speaks of many cases of epilepsy and of mania cured by restoring the balance of the ocular muscles, either by surgical aid or by use of prisms; in other words, by curing the heterophoria.

If the two eyes are caused to move in certain directions for a given distance, they may move in harmony and perfect co-ordination and balance may be maintained, but beyond this point one will waver, for its excursive capability is limited; the axes no longer maintain parallelism and the patient complains of seeing the object looked at as double. This may be true when looking in certain directions, or in all directions if past a certain distance from the median line. The power of abduction should not fall below five or six degrees. That is to say, a prism of 5° or 6° with base placed towards the nose, refracting the rays inward, should be overcome by the abductor .

So also should the adductors overcome a prism of 40° or 50° with base outward. Of course, exceptional cases exist, where the muscular power is much below this, with a perfect balance and no asthenopia.

As above said, these anomalies frequently exist unknown to the patient, and without careful and most searching examination with the various tests now known they will be overlooked even by the oculist. The physician not giving especial attention to such affections is at a loss to account for the persistency of pain, inability to read long

at a time, vertigo, headache, and many other symptoms.

In his vain effort to account for the trouble, he seeks its etiology in malaria, biliousness, liver disorder, gastric, uterine, or mental disturbances.

HOW TO TEST THE STRENGTH OF THE MUSCLES AND DETECT ANY EXISTING INSUFFICIENCY THEREOF. First, correct any existing ametropia. Place before the right eye a prism of 3° or 5° with base in the vertical, say upward, and have the patient look at a distant object. This prism will cause vertical diplopia, for the superior or inferior recti are capable of overcoming only a very low amount, say two or three degrees. If the two images are exactly one above the other, both being in the vertical line without any muscular effort, there is no insufficiency of either the internal or the external recti; or, in other words, the adductors and the abductors balance; but if the lower image—the one seen by the right eye—deviates to the right, we have homonymous diplopia from weakness of the abductors (*esophoria*). If this lower image goes to the left, we have heteronymous or crossed diplopia, due to insufficiency of the adductors (*exophoria*). In the first instance, the prism, with base outward, that will bring the two images into the vertical line will indicate the amount of esophoria. In the second instance, the prism, with base inward, that will bring the two images into the vertical line will show the amount of exophoria.

There are several tests for detecting heterophoria. If examining for near objects, we may

select the *vertical line test* and see if there is perfect equilibrium of the abductors and adductors. Employ a weak prism, say three to four degrees, with base vertically upward. The prism is placed in trial frames before say the right eye. The patient is then asked to look at a fine line with a dot in its center (Fig. 137) at a distance of twelve or fourteen inches from the eye. The prism has produced vertical diplopia. There are two images of the dot, one above the other, varying in distance according to the strength of the prism and the distance at which the line is held from the eye. If the two dots are in the vertical line, one exactly above the other (Fig. 138), there is perfect balance of the abductors and adductors. Frequently there is some wavering of the images, due to a slight weakness, which should not be accredited as a form of heterophoria; but if it exceeds four or five degrees, it should be so regarded.

Fig. 137. Fig. 138.

If the deviation is that of convergence, it shows a defectiveness of the abductors; for instance, with a prism placed with its base upward before the right eye, the rays passing through the prism will be bent toward the base and will impinge upon the retina above the yellow spot, and the image will be projected down. Now, if this image fall upon the vertical line exactly below the other, there is perfect balance of the abductor and adductor muscles; but if it goes to the right and below, it indicates convergence of the eye or insufficiency of the abductors, for here the im-

age impinges upon the retina inside the yellow spot, and is projected outward, suggesting weakness of the external rectus; but, as before said, if it be but a slight amount, it need not be considered an abnormality. If the lower image is thrown across to the left, it indicates divergence of the axes, or insufficiency of the adductors; for here the image impinges upon the retina outside of the yellow spot and is projected across; hence, a weakness of the internal recti or adductors. Now the prism that will correct these deviations and bring the image exactly upon the vertical line will show the amount of esophoria or exophoria, as the case may be.

In examination for heterophoria we should test the eyes for both near and remote objects, as there are many different forms and combinations. A muscle or set of muscles may be normal in function for near objects, but for remote objects may be insufficient, and *vice versa*. Again, there may be a defect for both remote and near objects. Not infrequently do we find a defective adduction both for near and distant objects, indicating an insufficiency of the externi; or defective abduction for remote and near objects, indicating faulty externi. Defective adduction for near but not for distant objects occasionally exists.

Defective abduction greater for working than for distant point is also found.

Defective *abduction* for distant and defective *adduction* for the working point—*i. e.*, insufficiency of externi for distant and of interni for near objects—is occasionally met with. (In this last con-

dition we should have homonymous diplopia for distant objects, but heteronymous or crossed diplopia for near objects.) In other cases we may have a debility or insufficiency of all the different muscles and for all distances, showing a general weakness.

Maddox has given us several most valuable tests for ascertaining these heretofore occult and troublesome affections. If we go through a fixed and settled form of revealing the different kinds of muscular insufficiencies, we shall then be in a better position to correct the same.

Fig. 139.

Maddox Rod Test. This instrument consists of a glass rod set in an opening of a metal disc (Fig. 139).

The rod should be placed in the anterior receptacle of the spectacle frame (the posterior receptacle holding the glass to correct any existing error of refraction). The glass rod acts as a strong cylindrical lens and causes the candle flame or gas light looked at to appear as a long streak of light. If the superior and inferior recti of the right eye are to be examined, the rod is placed vertically before this eye and the patient requested to look at a candle flame or gas light, with both eyes, at a distance of eighteen or twenty feet. The gas flame or jet is seen distinctly with the left, while with the right eye a long streak is seen extending horizontally.

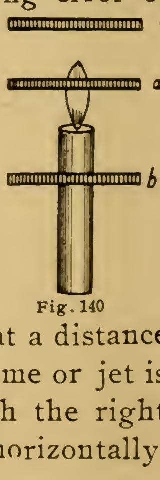


Fig. 140

Now, it is the left eye that fixes the flame, and if there be orthophoria, the streak will pass through the flame as is represented in Figure 140 (*a*). If there be hyperphoria, the streak will be below (*b*). If there be cataphoria, it will be above (*c*). The amount of heterophoria is indicated by the strength of the prism, placed before the eye, that will throw the streak into the normal position; viz, position *a*, Fig. 140. If hyperphoria be found in one eye, the other eye tested in the same way shows the same degree of cataphoria.

To test the adductors and abductors, the rod must be placed before the eye in the horizontal meridian. The streak will then appear vertically. If we first test the right eye, the gas jet at twenty feet will be distinctly seen by the left, while with the right a light streak will be seen in the vertical direction.

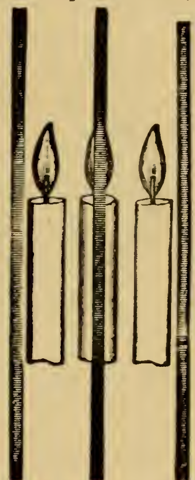


Fig. 141.

If there is perfect orthophoria, the streak will pass directly through the flame, as is represented in *a* (Fig. 141). If there be esophoria, the streak will be to the right (*b*); if exophoria, it will be to the left (*c*). Each eye being tested, it will be found that if there be esophoria of the right, there will also be esophoria of the left; and if there be exophoria of the right, there will be the same form in the left and of the same degree; the amount of which can readily be ascertained by the prism, placed before the eye, that will throw the light streak into the flame, as represented by *a*.

Maddox has another test which shows any compound muscular error, as it will indicate at once any defect of the vertical with that of the horizontal as well as the oblique muscles. This is his double prism test, consisting of two prisms set in a rim (Fig. 142) with bases together, having the effect of doubling objects. This is placed in the frame before, say the right eye, the left being covered by an opaque disc. The candle, door-knob, or object looked at, at twenty feet, will appear double if the base line of the prisms cuts the center of the pupil. The images of the object—the door-knob—will be separated to the distance of twelve or fourteen inches, one being directly above the other, as in Figure 143 *a*. Now, if the

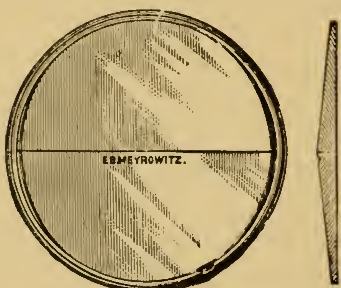


Fig 142.

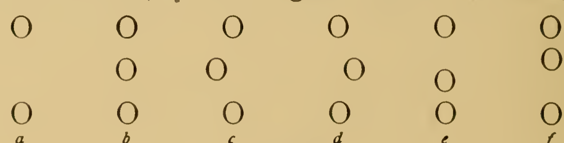


Fig. 143.

left eye is uncovered by removal of the opaque disc, another image will be seen between the two, and if there be orthophoria, the third will be exactly in the vertical line with the other two and midway, as is represented by *b*. But if the middle figure goes to the left (*c*), this indicates esophoria. If it goes to the right, it shows exophoria (*d*). Going nearer the lower figure indicates hyperphoria of the left eye (*e*). Going nearer the upper indicates left cataphoria (*f*). In the same

way, of course, the right eye may be tested and the degree of heterophoria ascertained by the strength of the prism required to throw the single image into its normal position; viz., in the vertical line midway between the other two (*b*). This double prism test can also be used in testing the muscles at a near point, as is beautifully shown by Dr. Savage, by using the *Von Graefe line and dot test.* First, place the double prism in the frame

a b c
Fig. 144.

before the right eye, covering the left with an opaque disc; then have the patient look at the line with dot (Figure 144, *a*), changing the position of the head, upward or downward, until the line and dot are seen as double (Figure 144, *b*). Now, if the left eye is uncovered, a third line will be seen, and if orthophoria exists, the third line will be midway between the other two, and its dot exactly in the vertical line with the other two dots (*c*). But,

a b
Fig. 145.

if there is esophoria, the middle dot will be to the left (Fig. 145, *a*). If there be exophoria, it will be to the right (*b*). If there be hyperphoria, it will be nearer the lower (Fig. 146, *a*). If there be cataphoria, it will go nearer the upper (*b*). If there be hyper-esophoria, the middle line will go to the left and below (Fig. 147, *a*). If there be hyper-exophoria, it will go to

a b
Fig. 146.

the right and below (*b*). If there be eso-cataphoria,

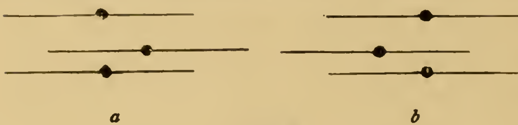


Fig. 147.

it will go to the upper and left (Fig. 148, *a*). If there be exo-cataphoria, it will go to the upper and right (*b*).

The following method is a very simple and speedy test or mode of detecting any insufficiency of the abductors or adductors. It

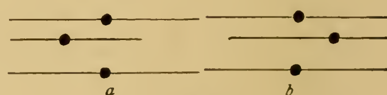
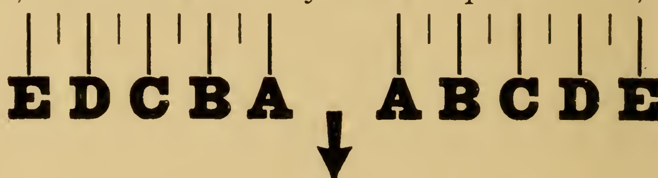


Fig. 148.

is with a card of double letters, A-B-C-D-E, one set red and the other black, separated by an arrow, shown in Figure 149. Place the card at twenty feet, then test either eye with a prism of 4°, say



(Black) (Red)

Fig. 149.

base down. The prism doubles the image and the person tested sees two cards, the false one being above, as shown in Figure 150.

If there is perfect balance, or orthophoria, the arrow of the false or upper card will point to the arrow of the lower card. But if there is esophoria, the arrow will go to the right (the right eye being the one tested), and if there is exophoria, it will go to the left.

As the space between each letter indicates 1°, the amount of insufficiency can be easily read off. As, for instance, if the arrow points to the letter A to the right (Figure 150), it would indicate 1°

of esophoria, showing an insufficiency of the abductors; if the arrow moves to the left and points to the letter A, it shows insufficiency of the adductors, or heteronymous diplopia, or exophoria to the amount of 1°.

Dr. Spencer has combined this with Stevens' phorometer, making a good test (Figs. 151 and

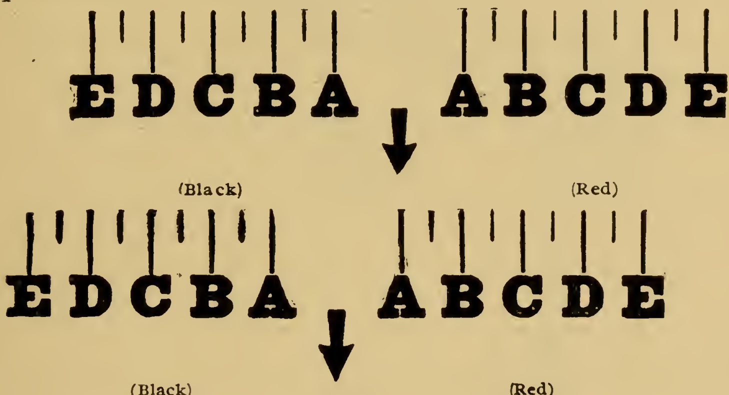


Fig. 150.

152). Stevens' phorometer is a scientific and accurate instrument. I give the following description as furnished by Meyrowitz Bros., the manufacturers, taken from their catalogue, pages 40 and 41:

"The instrument consists of the standard A supported by a tripod. The standard is freely extensible, permitting a ready adjustment for different statures of patients. The arm B is grooved and allows the prism carrier C to rest securely, to slide freely from end to end of the arm, or to be removed at will. At E a spirit level is attached to the arm, by means of which the horizontal position of the arm can be determined. The semicircular piece of the head of the arm is spirally

toothed and is acted upon by the endless screw at F, which imparts to the arm an upward and downward elbow movement. The semi-circle is graduated in degrees, and a fine pointer indicates the extent of motion imparted by the screw. By means

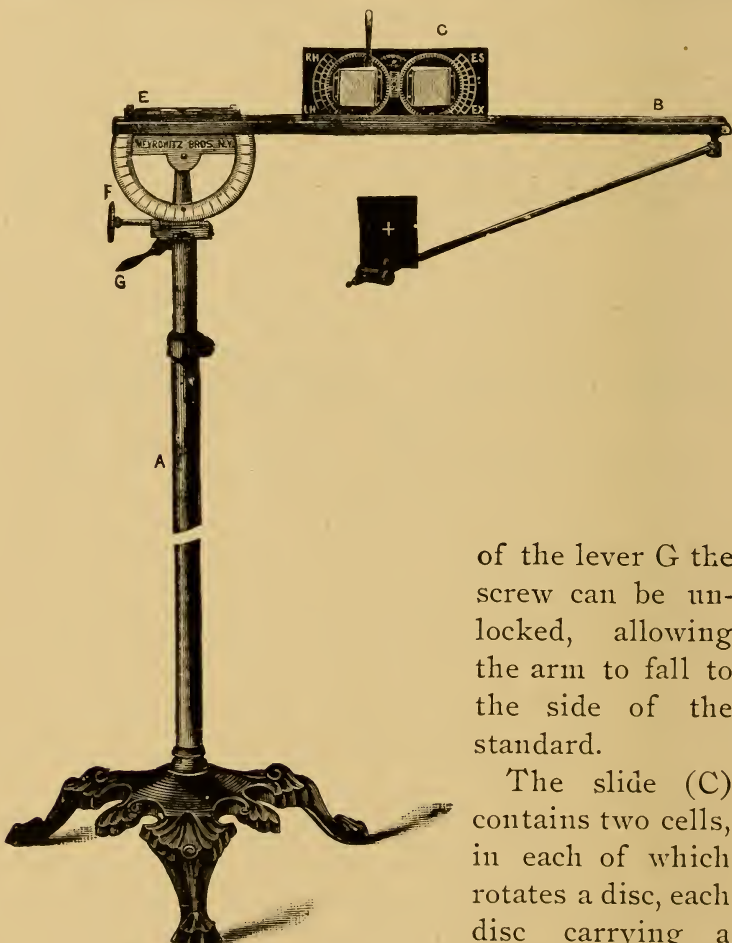


Fig. 151.

of the lever G the screw can be unlocked, allowing the arm to fall to the side of the standard.

The slide (C) contains two cells, in each of which rotates a disc, each disc carrying a prism of 5°. Each disc is furnished with a border of teeth or cogs. A small gear-wheel placed between the two discs

communicates the movements from one disc to another. Around the outer part of the border of each cell is a narrow raised band on which is marked a scale of degrees, increasing from the center each way from 0° to 8°, the number representing the refracting angle of prism—the method of notation now commonly used. A second scale just outside the first is similarly graduated, according to the new system of designating prisms by the refracting power or number of degrees of minimum deviation.

Fig. 152.

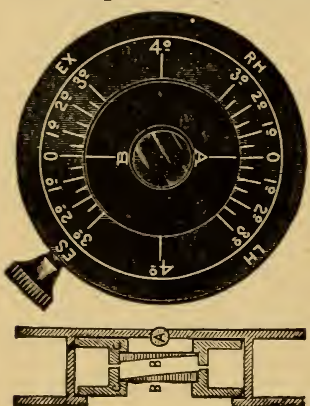
Directions.—To determine hyperphoria, bring the level of the prism slide to the vertical position, the pointer being at zero. The patient, looking through the glasses at a lighted candle twenty feet away, sees a double image of the candle. Should one of the images appear higher than the other, the prisms are caused to rotate until the images are brought to the same horizontal plane. The pointer then indicates the kind and amount of manifest hyperphoria.

To examine for esophoria and exophoria, bring the lever to a horizontal position and then make adjustments until the images are in an exact vertical line.

The supplemental prisms must be used with base in if the prisms in the instrument are not sufficiently strong to cause diplopia. If the prisms

in the instrument are so strong as to widely separate the images, the supplemental prism should be placed with the base out.

The accompanying cut represents Prince's phorometer, which is a convenient and reliable test for ascertaining the strength of the extrinsic ocular muscles, and is cheaper than Stevens's; however, we have found from actual practice that Maddox's double prism and rod tests (Figs. 139–142) take the place of these more expensive and complicated phorometers, are more easily applied, and are just as reliable and accurate in their revelation; in fact, they are even better for the examination and testing of the ocular muscles for both near and distant objects.



TREATMENT.

Refractive errors are to be first looked for, and if any exist, they must be accurately corrected, giving, as a rule, a full correction; especially is it necessary in hypermetropia when it is associated with esophoria, but if it is associated with exophoria only a partial correction should be made; on the other hand, in myopia with exophoria the full correction should be given, but only a partial correction when it is associated with esophoria. Hav-

ing ascertained the amount of heterophoria, if it be on the operative line, as indicated by Dr. Savage, then the kind of operation is to be determined, whether it be complete tenotomy or partial (graduated tenotomy, so called). If the heterophoria is of a low degree, all means should first be used to correct it without an operation. Frequently a slight heterophoria can be corrected by decentering the glasses required for the correction of the error of refraction; for, as is well known, either a convex or concave glass looked through excentrically acts as a simple prism. Muscular asthenopia without any error of refraction exists far more often than was formerly thought, and it is these cases that have so perplexed the general practitioner and even "stumped" the oculist. It is in these cases that we derive special benefit from the gymnastic exercises with prisms. Occasonally, partial tenotomy has to be made; but it is a rare case indeed that demands complete severing of the tendon. It is much better to under-correct and have to repeat the operation than over-correct and be obliged to advance the opposing muscle. In making graduated tenotomy, the outer fibres above and below or the central fibres may be severed. Of course if there is mixed heterophoria, say hyper-esophoria, then the upper fibres should be the ones severed. Ordinarily, the central fibres are the ones to be selected. The operation should be made under the influence of an anæsthetic of cocaine of 8 per cent. The incision should be directly through the conjunctiva; the tendon is grasped by means of a delicate rat-toothed forceps near its insertion, and

with delicate, blunt, slightly curved scissors the fibres are severed close to their scleral attachment.

The eyes should be immediately tested to ascertain if the correction is sufficient. Besides the correcting of the heterophoria by glasses and by operation, other measures must be used. In the first place, the patient's general health should be looked after; he must be supported by tonics, by good food, and hygienic surroundings; rest from all work with the eyes for a time should be enjoined, proper exercise, horse-back riding, gymnastics in the open air judiciously directed, massage, Turkish bath, etc. Often the muscles may be strengthened by a course of gymnastics with prisms. It is best to have the patient visit the office daily and wear a prism of a certain degree before each eye, say for an hour or so, increasing the strength from day to day. First wear base inward and then outward. If it is desirable to strengthen the superior or inferior recti, a weak prism with its base upward or downward may be employed as in exercising the adductors and abductors. In this way the strength of the muscles can be augmented. Care should be taken not to give too strong a prism at first, nor should the prisms be worn too long at a time. It is sometimes a good plan for the patient to use the eyes for near work a certain length of time every day.

Dr. Savage has suggested a plan of gymnastic exercise with prisms which I have adopted and found to give satisfactory results. Dr. Savage calls it the "Rhythmic Exercise with Prisms." In giving this exercise, place a weak prism before

each eye, sufficient to produce diplopia, yet not so strong but with a little effort they can be overcome and the two images fused. As soon as the images run together, the patient raises the prisms, when, for an instant, he sees double; and as soon as the images are again fused the prisms are dropped before the eyes, when the patient again sees double, but only for an instant, as the two images will immediately shoot one into the other. Then the prisms are again lifted, and so this rhythmical exercise is continued for a few moments, thus exercising the muscles of the eye and augmenting their strength. By placing the bases in different directions, any one or set of muscles may be thus exercised and strengthened.

Static electricity applied to the eye-ball and up and down the spine three to five minutes daily I have found to give relief and to be of permanent benefit.

How to Detect and Correct Insufficiency of the Oblique Muscles According to Savage. "Place a double prism (Maddox's prism) before one eye, the other, for a moment, being covered with an opaque disc. Ask the patient to look at a horizontal line on a card held 18 inches away. The effect of the double prism is to make the line appear as two, each parallel with the other. The other eye is now uncovered, and a third line is seen between the two, with which it should be perfectly parallel. If there is a want of harmony on the part of the oblique muscles, this test will show it at once in a want of parallelism of the middle with the two other lines, the right end of the

middle line pointing towards the bottom, and the left end towards the top, or *vice versa*, depending upon the nature of the individual case. The eye before which there is no prism is the one being tested; as, for instance, with a prism before the right eye, the patient's attention is directed to the middle line, which he sees with the left, If it is nearer the bottom, it shows left hyperphoria; if nearer the top, left cataphoria; if to the right, exophoria; to the left, esophoria. If the right ends of the middle and bottom lines converge, while the left ends diverge, the superior oblique of the left eye is shown to be below the normal strength. A, Figure 153, represents such a condition; B shows a weakness of the inferior oblique of the left eye. C shows a deviation of parallelism, being due to underaction of the superior oblique of the right eye. D shows a weakness of the inferior oblique of the right eye."

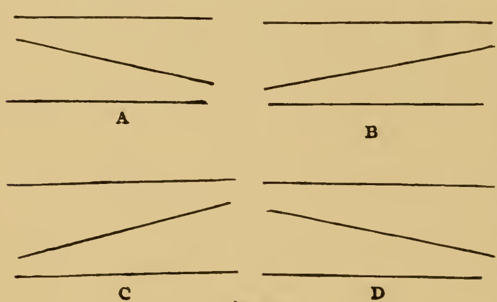


Fig. 153.

TREATMENT.

"In the treatment, either concave or convex cylinders can be used, and if the insufficiency is in the superior oblique, the axis of the concave cylinder must be placed in the lower nasal quadrant. If in the inferior oblique, the axis must be placed in the lower temporal quadrant. If, for exercise, the con-

vex cylinders are chosen, the axis must be placed in the lower temporal quadrant for insufficiency of the superior obliques, and in the lower nasal quadrant for insufficiency of the superior obliques. The exercise may be commenced with a 0.50 D. to 1.00 D. cylinder, and increased each day from 0.50 D to 3.00 D. The time should not exceed twelve or fifteen minutes daily. The rythmic exercise, as in other forms of heterophoria, can be used to advantage."

CHAPTER XII.

STRABISMUS.

Strabismus is the term given to that condition of the eyes in which there is a deviation of the axes from parallelism or the normal, and in consequence of this deviation the two eyes do not fix an object simultaneously, although each may have a normal range of vision. As a rule, there is no diplopia (double vision), and the muscular error is functional, there being no paralysis. When paralysis exists, both eyes in certain meridians may fix an object at the same time, but in other directions one or the other eye will lag on account of paralysis of a certain muscle or muscles, and, as a rule, there is double vision in certain parts of the visual field. In paralysis or paresis of the extrinsic ocular muscles the deviation is not universal, only experienced in certain directions, and the habit of suppressing one image is less readily formed. Also, the deviation being variable, the image of the object is constantly flitting on and about the yellow spot, now exactly blending with the image of the fellow eye and again moving to one or another side; consequently more or less double vision is experienced.

In what is ordinarily known as strabismus there is a deviation of the eyes from the normal, and hence but one eye fixes the object at a

time, while the image of the object falls to one side of the yellow spot in the fellow eye and is ignored, thus preventing diplopia. If, however, the strabismus is very slight, the image will impinge upon the retina near the yellow spot and the patient not infrequently complains of diplopia.

Strabismus may be permanent or temporary. Of the different kinds of strabismus, we have *strabismus convergens* (inward), *strabismus divergens* (outward), *strabismus sursumvergens* (upward), and *strabismus deorsumvergens* (downward). If but one eye deviates, we call it *monocular* strabismus. In case of both axes deviating it is called *binocular* strabismus. If first one eye fixes the object and then the other, it is called *alternating*. Occasionally in convergent and divergent strabismus one eye will turn upward or downward as well as inward and outward; especially is this true in convergent strabismus. In the case of monocular strabismus the eye that does not fix the object is not equal in its vision to that of its fellow, whereas in alternating strabismus the vision of each eye is equally good. The angle of deviation is frequently greater in one eye than in the other; that is to say, one eye has a wider range of excursion than the other. When the deviation of each eye is the same, it is called *concomitant* strabismus.

Fig 154.

To measure the strabismus several kinds of instruments have been devised, but no one of itself is perfectly satisfactory. Fig. 154 represents one of these instruments. The ordinary method of measurement is to have the patient fix an object at a distance (which he does with one eye), then mark the lower lids with pen and ink opposite the cen-

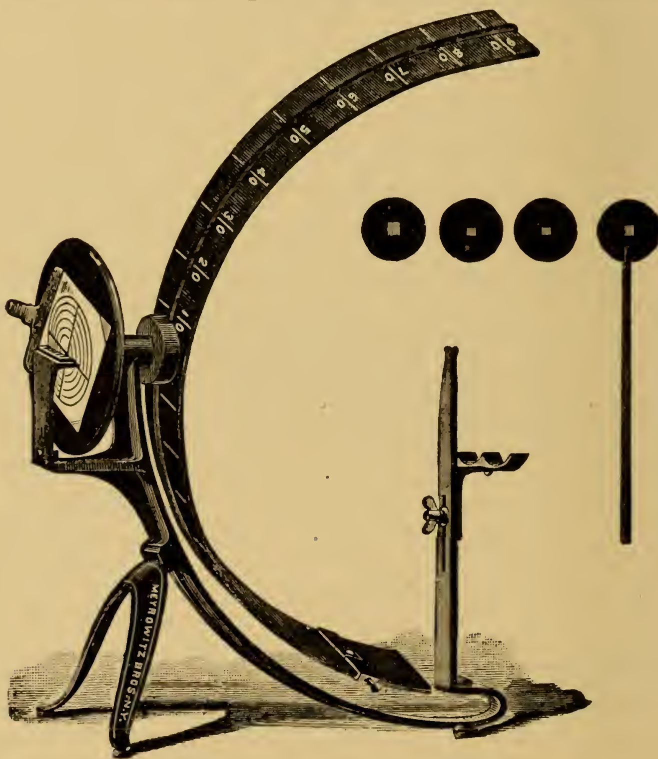


Fig. 155.

ter of the pupil of each eye; screen the eye fixed and cause the patient to look at the object with the other eye and while this eye is fixed mark the lids of both eyes opposite their pupils as before. Now, if the distances between the marks upon the lids of each eye be equal, the

strabismus is concomitant and the amount can be estimated in mm. However, this is not an accurate method. The more nearly correct method is to take the measurement in degrees by means of the perimeter (Fig. 155).

To obtain the angle of deviation in degrees, place the patient in front of the perimeter with the arc horizontal. Have the patient look at an object at a distance of several feet in a line with the zero of the arc, which is at the center; then by moving a lighted candle or lamp along the arc until the image of its flame is seen in the center of the pupil of the deviating eye, the number on the arc opposite the flame will indicate the degree of deviation. In case of a high degree of convergent strabismus when the squinting eye turns in under the nose so as not to admit of a reflex of the candle flame, a prism may be used that will cause the light to be thrown on to the center of the cornea, and half of the strength of the prism added to the amount given by the perimeter will equal the degree of strabismus. Any deviation upward or downward can in a similar way be ascertained. In high degrees of myopia where the optic axis is at the inner side of the visual line there is an apparent convergent strabismus.

CAUSES.

The mother or attendant usually attributes the cause to a fall, fright, spasm, or some disease of childhood. She will tell you that Johnny's or Mary's eyes were perfectly straight until he or she had the measles, whooping-cough, mumps, diph-

theria, etc., or until the eyes of the child were exposed to a strong light. You will almost always be informed, however, that the strabismus appeared about the fourth or fifth year of age, sometimes earlier and again later; usually about the time the child begins to use its power of accommodation; as when learning to read.

Among the real causes of strabismus the most frequent are: hypermetropia, myopia, amblyopia, muscular insufficiency, opacity of cornea, monocular cataract, monocular amblyopia, atrophy of optic nerve, scotomata, etc. In convergent strabismus, hypermetropia is responsible for about eighty per cent; while in divergent strabismus, myopia is associated with a large per cent. Occasionally, divergent strabismus results from an operation for convergent strabismus, too free division of the internal rectus having been made. Schweigger finds that among 325 cases of convergent strabismus 85 were emmetropic, 44 were myopic, and 196 hyperopic; and in 100 cases of divergent strabismus 37 were emmetropic, 59 myopic, and 4 were hyperopic. Horner finds that in 236 cases of convergent strabismus 4 were emmetropic, 11 myopic, 13 were antimetropic (one eye myopic, the other hyperopic), and 208 hyperopic. In 133 cases of divergent strabismus, 3 were emmetropic, 62 myopic, 30 antimetropic, and 38 hyperopic. In hypermetropia, as we have seen, the power of accommodation is brought constantly into use, whether the eye is regarding near or distant objects, and the higher the degree of hypermetropia the greater is the demand upon the accommodative power of the

eye. It has been shown by Donders that the effect of accommodation is facilitated by convergence of the eyes. So in the hyperopic eye the adductors are brought much into use, until finally there is a preponderance of power developed in the internal recti over that of the external recti, and convergent squint is induced. In myopia, when the eye is adjusted for near objects or for divergent rays, there is no necessity for exercising the accommodative power and the adductor muscles; consequently, there is no convergence, and for want of stimulus the internal recti may become inert and the abductors gain preponderance of power, resulting in divergent strabismus. In case of monocular corneal opacity, cataract, or amblyopia from other causes, the defective eye does not fix the object observed and is allowed to turn at will uncontrolled; this may result in divergence or convergence.

Astigmatism, anisometropia, and antimetropia are frequently associated with strabismus. In a slight amount of strabismus there is occasionally diplopia due to some form of heterophoria, but it is only when one image laps over or is near the other. This complication can frequently be corrected by simply decentering the glass required to correct the anomaly of refraction; or if there be no anomaly of refraction, but simply a muscular asthenopia, simple prisms with their bases turned toward the muscles to be relieved may suffice. Where there is decided deviation the image impinges upon the retina of the deviating eye so far from the macula that no cognizance is taken

of it; that is to say, the image is ignored or suppressed, and then, from disuse, this eye suffers, and its vision frequently becomes seriously impaired. If the axes converge, the diplopia will be homonymous; if they diverge, it will be heteronymous.

Time of Appearance of Strabismus.—Strabismus may be congenital, appearing at birth, but is usually not noticed until the child begins to fix its vision upon small objects, as, for instance, when it begins to learn to read; or, in other words, when it first brings its power of accommodation into use. The muscles of accommodation and those of adduction have their innervation from the same source, and when the former are brought into requisition there is an associated movement of the latter.

Divergent strabismus appears, as a rule, much later in life than convergent, especially if it is dependent upon myopia, as myopia does not exist at birth and is usually several years in reaching its highest degree of development. It is very seldom that strabismus sursumvergens or deorsumvergens exists unassociated with convergent or divergent strabismus.

TREATMENT.

In slight degrees of strabismus at its incipiency, if there be ametropia or muscular asthenopia, the glasses required for the ametropia or the asthenopia will occasionally correct the strabismus. Eserine may be used to relieve the ciliary muscle, and hence, the accommodative power; or atropine to wholly suspend its action. In prescribing glasses for strabismus depending on myopia or hyperme-

tropia, the weaker muscles can also be relieved by decentering the glasses required to correct the error of refraction; as, for instance, in hyperopia the convex glass decentered outward has the effect of a prism with base outward, thus relieving the external rectus. In myopia the concave glass should also be decentered outward, that the base of the prism be towards the nose, thus relieving the internal rectus. However, the effect of prisms has not thus far proven always satisfactory.

In cases of strabismus of a considerable degree, and once permanently developed, no other treatment than tenotomy will suffice. Frequently the patient with strabismus, especially if convergent, will complain of a drawing sensation or a tension with pain in the eyes. This is due to the continued strain of the internal recti muscles drawing the eyes inward, and no treatment will relieve this other than tenotomy of the internal recti muscles; and then, if there be any anomaly of refraction, it should be corrected by the required glasses. In high degrees of convergent strabismus, or in case of weak abductors, the external recti have to be advanced.

When should tenotomy be made? As a rule, the operation should not be made under four years of age, neither should it be delayed beyond the sixth or eighth year; for, at first, the squint is alternating and the vision is equally good in both eyes; but if the child is allowed to go on with the deviation, after a time it learns to look with but one eye, ignoring the image of the other so as to avoid double vision, and then, from disuse, the eye

not fixing may become irreparably injured. The object of tenotomy is then not only to improve the appearance of the child, but to preserve sight and prevent other complications which are liable to arise from the anomaly, if long neglected; such as impaired vision, severe pain in the eye, frontal and temporal headaches, St. Vitus's dance, and even insanity. It is, I repeat, very important that a timely operation and adjustment of glasses be made; but the operation must be carefully and judiciously made. The manner and extent of the operation should be governed by the amount of strabismus and the amount of error of refraction. *There should never be too free a dissection of one muscle, but rather a partial tenotomy of the muscle in each eye* (excepting strabismus sursumvergens and strabismus deorsumvergens). If there be but a slight deviation, say three or four mm., and it seems to be confined to one eye, an operation may be limited to this eye; but in ninety per cent of all cases both eyes should be operated upon; that is to say, in case of convergent strabismus both internal recti are at fault and the operation should be divided between the two eyes. If there be but a slight amount of deviation, it may be advisable to make graduated tenotomy, severing only a part of the tendon fibres, say the central ones; if this does not suffice, the operation can be repeated. The extent of the excision should be governed by the amount of deviation to be corrected. If the operation be confined to one eye and a free dissection of the muscle be made, an over-correction is liable to follow, and then the delicate operation of advance-

ment to correct this fault must be made. The young lady (Fig. 156) was operated upon for convergent strabismus when a child. The operation was confined to one eye, a free division and dissection of the internal rectus was evidently made, and the result was that the eye turned

Fig. 156.

Fig. 157.

outward, with marked lagophthalmus. Disfigurement from the operation, besides the loss of the eye from disuse, resulted. In this case, to correct the fault I was obliged to advance the internal rectus; as merely dividing the external would not correct the divergence. I found

the internal muscle so atrophied that there were merely a few shreds of tendon remaining, but I succeeded in attaching them to the sclera by means of the conjunctiva near the margin of the cornea. The vision of the deviating eye previous to the operation, December 10, 1891, was $\frac{8}{100}$; ten days subsequent to the operation, when the second photograph was taken (Fig. 157), the vision of the eye was $\frac{20}{100}$; showing a decided improvement by correcting the deviation so as to bring the eye into co-ordination with its fellow, thus allowing the images of objects looked at to fall upon its macula lutea. The cosmetic effect, as the photograph (Fig. 157) shows, is all that could be desired, as the divergence is accurately corrected and the lagophthalmus nearly so; which, to the young lady, being a singer, was of paramount consideration.

In case of divergent strabismus with myopia it is, as a rule, advisable to advance the internal rectus as well as to tenotomize the external, for the internal muscle in these cases is usually insufficient, and tenotomy alone of the external does not suffice. Also in a very pronounced case of convergent strabismus, especially if it is associated with a high degree of hypermetropia, it is frequently advisable to advance the external as well as to sever the internal rectus; in fact, in many cases a complete correction of the squint cannot be secured without resorting to advancement of the external.

The question of dealing with strabismus in its different forms with the various phases and complications is of greater magnitude than is generally thought; and simply making tenotomy of cer-

tain tendons is by no means the only consideration. It is often a grave question whether tenotomy, especially in children, should be made. Frequently the affection among these little patients can be corrected without resorting to surgical interference; besides, if the operation is not properly and judiciously made, sequences may follow which prove even more disastrous than the previous condition. *The general practitioner, unless he is prepared and is able to cope with all the different phases and complications that may arise, being competent of eliciting and detecting the different forms of heterophoria and the anomalies of refraction, correcting the same, is not warranted in undertaking to operate upon these cases.* While it is not difficult to sever the tendon, yet it is frequently most difficult to correct the strabismus and obtain perfect results.

As has been said, convergent strabismus especially must be corrected early; for here the deviating eye soon learns to suppress the image, and from want of stimulus or from disuse becomes irretrievably impaired in its vision.

The steps for advancement are as follows:

Separate the lids with speculum; grasp the conjunctiva with rat-toothed forceps near the margin of cornea opposite the insertion of muscle; dissect down to the muscle, exposing the tendon; then, with strabismus hook, hook up the tendon, rendering it tense, clip off the external fibres of the insertion, also clip away any redundancy of conjunctiva on either side; then, with curved needle threaded with silk, pass through conjunctiva at

superior portion at the margin of the cornea, then through tendon at its insertion, then pass through the conjunctiva above opposite the point of the insertion of the tendon. Pass a second curved needle threaded with silk through the conjunctiva, at the limbus inferior portion, thence through the lower portion of the tendon, lastly through the

Fig. 158.

conjunctiva opposite the insertion of tendon. Then, with curved scissors with convex surface next to the sclera, clip off the remaining portion of tendon as close to the insertion as possible, taking care not to sever the silk. The sutures should be inserted into the conjunctiva at equal distance above and below the line of tendon or muscle, so that

when they are tied they advance the muscle, which reattaches itself in its original direction.

On advancing in pronounced cases it is usually necessary to make tenotomy of the opposing muscle. Care must be exercised in this not to clip too freely, or over-correction and lagophthalmus may result.

Fig. 159.

In the child, Susie H——, of Shockley, Neb., aged four years (Fig. 158), the convergence was alternating, although largely confined to the left eye. The ophthalmoscope showed five and one-half dioptres of hyperopia, and the angle of deviation was over fifty-five degrees in each eye, according to the perimeter. In this case, I made complete tenotomy of both internal recti, with the

result, as the picture shows (Fig. 159), of completely correcting the strabismus. The picture was taken one week subsequent to the operation, January 8, 1892. In this case, immediately after the operation, the left eye deviated outward, but with the glasses it soon came to the proper position.

The picture of Miss Flora B—— (Plate X), aged 20, shows a convergent strabismus, which was alternating without any manifest hyperopia; the vision of either eye was $\frac{20}{20}$. The convergent strabismus of the right eye was 5 mm., and of the left 7 mm. The left eye was 2 mm. higher than the right. Complete mydriasis revealed a slight amount of hyperopic astigmatism of either eye, but scarcely more than is found in the ordinary so-called emmetropic eye. In this case it was necessary to make complete tenotomy of the internal rectus of each eye, as both muscles were strongly developed; and to correct the sursumvergens I also made tenotomy of the superior rectus of the left eye, thus restoring perfect balance of the several ocular muscles, as the picture (Plate XI) indicates.

The glasses, with the operation, have dispelled all asthenopic symptoms, and the worried, anxious expression with the facial lineaments has disappeared, giving place to a complacent, amiable expression, which is really the true index of her disposition, as shown by the picture (Plate XI).

An interesting feature of this case is that here we had a decided convergent strabismus with scarcely any ametropia, and no hereditary tendency.

Plate X.

Plate XI.

The slight hyperopic astigmatism was corrected by a +0.25 D. C., axis 90°.

Steps of the Operation of Tenotomy.—Having thoroughly cocainized the eyes with an eight per cent solution and rendered them aseptic by thoroughly flushing the conjunctival sac with boric acid solution, we lay out the necessary instruments and are then ready for the operation.

We place the patient upon the table, separate the lids with Noyes's speculum; with forceps, grasp the conjunctiva just below and within the insertion of the tendon, then, with blunt-pointed scissors, snip through the conjunctiva and subconjunctiva, insert the scissors, and by a few clips free the insertion from surrounding tissue, then insert the strabismus hook back of the muscle insertion, draw the hook forward, taking care to gather all of the fibres of the tendon. Making tense the muscle, insert the blunt-pointed curved scissors, convex surface next to the sclera, between the eye and the hook, and sever the tendon as close to the sclera as possible. If the hook now passes freely up to the limbus, the entire tendon is severed. We pass through the same steps with the other eye.

There is an advantage in the subconjunctival tenotomy over the dissecting from the limbus down to the tendon, as there is not the disfigurement of the eye by a sinking of the caruncula.

The after-treatment consists simply in bandaging the eyes for a few days, cleansing with antiseptic lotions, and the adjustment of required glasses on the removal of the bandage. If there

be hyperopia or astigmatism, it is absolutely essential that they be corrected by prompt and continuous use of proper glasses.

The boy (Fig. 160) was operated on at the clinic and satisfactory results were obtained, but he failed

Fig. 160.

to come back. I saw him a few weeks after the operation, when the eyes had again deviated inward, because he had neglected to wear his glasses. This is an example of one of the failures, or partial failures, incident to neglect upon the part of the patient to wear the glasses prescribed for his ametropia.

Plate XII.

1. 2.

Walter B——, aged 12, came to the clinic December 8, 1893, with the following history: "Mother had six children, the youngest being seven years of age, the oldest twenty-four. Nearly all have some defective sight. This boy had successive attacks of brain trouble between the ages of two and a half and nine years. Lost sight of right eye entirely at six years, but recovered partially as health grew better. Had convulsions regularly from 5 P. M. till midnight when the sight of the right eye was lost. The eyes were operated upon twice by an oculist, first in January, 1892, and again in February, 1892; but with little or no benefit" (Fig 1).

Vision of right eye = 20–160; with + 1.50 D., = 20–120.

Vision of left eye = 20–40; with + 0.50 D., = 20–30.

The ophthalmoscope did not show any pathological condition of the retina of the amblyopic eye, though glasses would improve the vision of this eye but slightly. A mydriatic revealed hyperopia 3.50 D. of the left eye. The angle of deviation of the right eye was about fifty degrees. There was such a preponderance of power of the adductors in this case, and weakness of the abductors, that it was necessary to make advancement of the external rectus of the right eye, as well as tenotomy of both externi. This operation was made December 16, 1893. December 23, R + 1.50s. D. either eye.

The second photograph (2) was taken three weeks subsequent to the operation, illustrating, as it does, a perfect correction of the squint. The vision of the right eye January 26, 1894, was 20–100; that of the left 20–30, showing a considerable improvement in the vision of the amblyopic eye, brought about by the operation and use of glasses.

CHAPTER XIII.

SPECTACLES.

Under the head of spectacles I wish to call especial attention to the different forms of eye-glasses, and to the necessity of a perfect fit as to size, form, and style, as well as to the adjustment to the nose and face. In selecting glasses, it is of great necessity that they be secured to correct not only the errors of refraction, but also the anomalies of the extrinsic muscles. The oculist ferrets out the anomaly, prescribes the glasses with measurements as to size and style of frames, etc., and the optician should see that the mechanical part is perfectly done, and that the prescription is accurately filled; for if the glasses are not properly adjusted, they will not accomplish what is expected of them, and may even prove injurious. It is the optician's business, first, to see that the glass has its principal axis in its center (Fig. 161), for if the axis is eccentric, as shown in Fig. 162, bringing the center of such a glass opposite the pupil would not bring its optical center into the visual axis. The optician then should see that

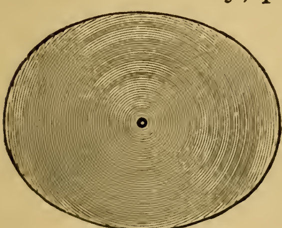


Fig. 161.

Fig. 162.

the glass is truly centered and that the center of each glass is opposite the pupil of the corresponding eye. (Figs. 163 and 164).


Fig. 163.

If the frames are too large, too small, or are not properly poised, but are tilted, as in Figs. 165 and 166, or decentered, as in Figs. 167, 168, 169, the eye does not look through the center of the glass, but some other part. This produces the effect of a prism, and inordinately taxes certain muscles, provoking asthenopic symptoms. Care must be taken also that the glasses are properly poised on the nose, at the right height and distance from the eyes. If they are too high, the person looks through the lower edge, or goes with head bowed; or if they are set too low, he must look through the upper edge, or go with head thrown back. If the glasses are set too near, the lashes are constantly striking them. A concave glass should be placed as near the eye as possible without interfering with the lashes; if not, the peripheral rays will not enter the pupil, and

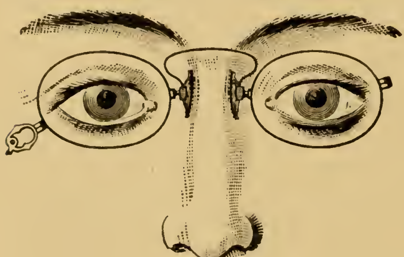


Fig. 164.


Fig. 165.


Fig. 166.

hence the retinal image will be smaller. The converse of this holds true with a convex glass, for the further away the lens is (up to a certain limit), the more convergent the rays come to the eye and

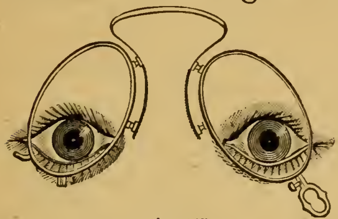


Fig. 167.

more will enter the pupil, and brighter and larger will be the image. If they are too far, the distance changes their focal power. Great care should be taken in selecting the saddle, or nose-piece. See that it not only fits the nose, but carries the glasses at the proper height and distance from the eyes. If the saddle is too narrow and pinches

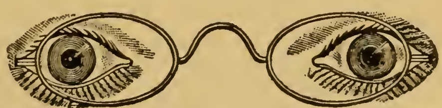


Fig. 168.

the nose, it may provoke disease of the lachrymal apparatus. The size and style of the glass must be selected to suit the individual features.

In taking the measurement of the spectacles,

Fig. 169.

the pupillary distance is the principal consideration, and next to that in importance is the selection of the saddle or nose-piece. People with a low or flat nose-bridge are not able to wear a *pince nez*. The glasses for distant objects should set higher than those for near objects. Reading glasses should be in such a position as to permit seeing through the center without bowing the head, but merely lowering the eyes or directing the eye to an angle of 45° when the head is erect.

The temples of the spectacles should rest on the ears. If one ear is a little higher than the other, which is not uncommon, the bow should be correspondingly bent or tilted. No optician nowadays would think of giving to a child the same size frame and glass as to an adult; yet it is but a few years since any attention has been given to the special fitting of glasses to children.

The nose-piece should have sufficient flat surface so as not to cut the nose; a cork pad is light, aseptic, and prevents the saddle from cutting the nose. The width of the frames should be sufficient so as not to press too snugly the temples, and if the bows be hooked (Fig. 170), they must not hug

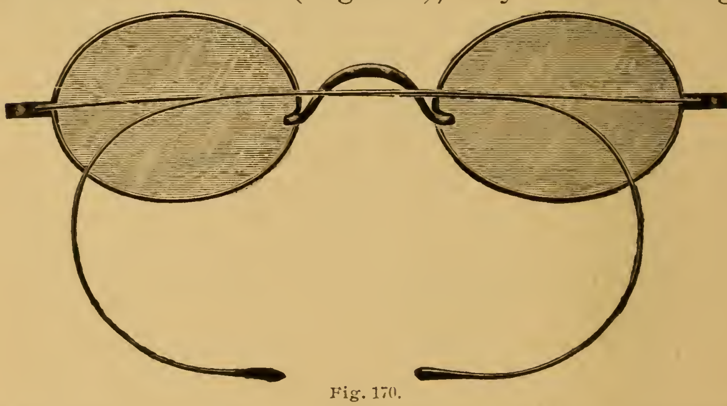


Fig. 170.

too closely the ears. Patients frequently complain of the bows cutting the ears, and so they put them through the hair; this is liable to tilt the glasses.

All these little details should be carefully looked after by the optician, for, as may be seen by the foregoing, the success of the glasses prescribed by the oculist depends much upon the optician, the relation of the latter to the former being similar to that of the druggist to the physician.

Many patients object to wearing spectacles in the ordinary frames (Fig. 171), and prefer the nose-glass (Fig. 172). If the glasses are to be worn only for reading, sewing, or for near objects, the nose-

Fig. 172.

glass is allowable; but if they are for constant use, the hook frames are best. The pinch-nose, for many people, especially for those of nervous temperament, is a source of annoyance, and produces or aggravates a neuralgic headache. If the pinch-nose is prescribed, it should fit properly and the spring should not be too strong.

Fig. 171.

As before said, frequently patients come to us with frames which they perhaps have received as a present, or as heirlooms, wishing to have glasses set in them. These frames may be too wide or too narrow, and in no way fit the face, and, if used, would certainly do harm to the eyes. What mother would think of giving to the child grandmother's gloves or grandfather's boots, expecting the child to wear these heirlooms? Certainly this important little organ of vision, with its delicate mechanism, should be worthy of as much consideration as these other

members of the body. If cylindrical glasses are prescribed, they would better be placed in spectacle frames, with hook bows, that the axis be secured in the desired meridian; especially if the glasses are for constant use. For myopes the hook frames are preferable. If the patient with astigmatism is desirous of using only the pinch-nose, the bar frame (Fig. 173) should be prescribed, as this more surely secures the axis of the cylinder in the required meridian.

Fig. 173.

For children, gold frames are the best, as steel will soon rust and break.

PROTECTING GLASSES.

As protecting glasses, the blue seem to be the best. It was thought at one time that the red rays were more irritating, hence green glasses, which exclude the red, were much in vogue; but it is not the red, but the orange rays which are irritating to the retina, and hence the blue glass, which excludes the orange rays, is the most pleasant to the eye.

A large oval concavo-convex blue or smoked is the best; green should not be used. These protecting glasses are liable to be poorly made, and of an inferior quality of glass; and so it is of importance that they be selected with care. They are of benefit in subduing the bright glare of the sunlight, especially at the seaside or in the tropics. They are also of benefit in protecting the eye from the glare of the white snow, and after the

use of a mydriatic. They are frequently useful in protecting the eye after cataract extraction, in retinitis, and, in fact, in any condition where there is photophobia. The large glasses set in aluminum frames (Fig. 174), are of special use as protecting glasses for gripmen, firemen, brakemen, stone-cutters, etc. Goggles with wire gauze (Fig. 175) should be denounced and discarded, for if they are long worn they are sure to provoke inflammation of the conjunctiva. They retain the heat and effluvium of the body, and act as incubators for germs. They are very frequently responsible for granulated lids, and for pannus with other complications. Patients get in the habit of using goggles, and it is almost impossible to induce them to leave them off, but so long as they persist in using them so long will their eyes continue to be sore. If their use were entirely abandoned, there would be as a result a large decrease of "sore eyes." The shade (Fig. 176) is useful as a protector both from wind and dust as well as from bright light; also when reading or sewing.

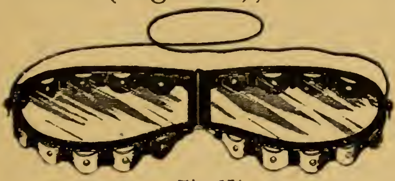


Fig. 174.


Fig. 175.

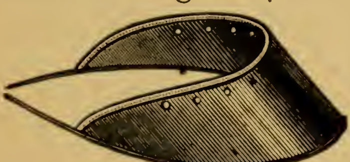


Fig. 176.

BIFOCAL LENSES.

A bifocal lens consists of two parts differing in their focus. In hyperopia or presbyopia, the upper is the weaker for distant, the lower being stronger

for near objects; in myopia, the upper should be the stronger, and the lower the weaker glass.

The convex bifocal lenses have been used for a number of years as "split glasses" (Fig. 177); but recently they are rendered less conspicuous, and therefore less objectionable, by the cementing of a small thin segment to the lower part, thus increasing the focal power of this part of the glass (Fig. 178).

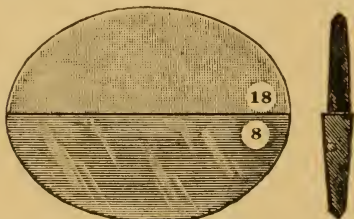


Fig. 177.

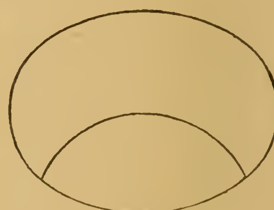


Fig. 178.

An attempt has been made to grind a solid lens with the lower portion of a stronger focal power (Fig. 179), but as yet such lenses are imperfect in their construction and have not proven satisfactory.

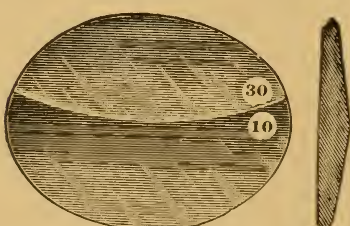


Fig. 179.

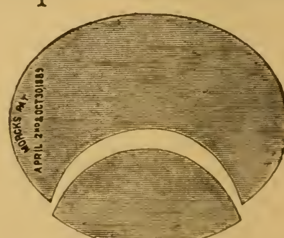


Fig. 180.

What is known as the "Perfection" (Fig. 180) has given better satisfaction. This consists in cutting out the lower part of the glass for distant objects, and fitting the reading lens in its place. These glasses are convenient for hyperopic persons after they have become presbyopic; especially are they appreciated by public speakers and readers,

who have occasion to change their vision constantly from distant to near objects and *vice versa;* but, on account of the limited field of the lower segment, they are not to be recommended for constant use.

It has been suggested that these glasses be also used by aphakic people, thus enabling them to see distant and near objects with the same spectacles; but, from the chromatic aberration of these glasses, they are not satisfactory.

For the public speaker who is simply presbyopic, the half eye-glass is convenient, especially if he needs to refer to his notes or manuscript.

It is of importance that the oculist as well as the optician be able to ascertain the strength of glasses, as frequently it is the case that glasses put up in large quantities are accidentally thrown into the wrong box and the strength falsely marked. So it is not always safe to trust the number indicated on the glass by the shipper.

To ascertain the strength of the glass, find its focal distance by holding the glass in front of a candle flame or a window and see where the image is distinctly formed on a white background, as a piece of paper. Or, find the glass that will exactly neutralize the one being tested; as for instance, if measuring a convex glass, place a concave glass in proximity to the other which will exactly neutralize the convex. The concave glass can be tested in a similar way. If you can see through the two as clearly as you see with the naked eye, you may know that the two glasses are neutralized.

In conducting the examination, if you move the glasses in front of the eye when looking at a dis-

tant object, as the test card, if the letters remain stationary, you may know that one glass neutralizes the other; but if the glasses do not neutralize each other, the letters will shift as the glasses are moved before the eyes one way or the other. If the plus glass is the stronger, they will move in the opposite direction; if the concave is the stronger, they will move in the same direction that the glasses are moved in front of the eyes.

The Lens Measure, as described in the Appendix, is also useful in ascertaining the strength and axis of glasses.

The *dioptric* (*dia*, through; and *optomai*, I see) is a substitute for the term *meter*, and is now used by oculists instead of the inch measure, thus gaining uniform measurement throughout the world, as the inch is not uniform.

A *dioptre* corresponds to 39.37 inches. For practical purposes, we call it 40; that is to say, a glass of one dioptre has the effect of bringing parallel rays to a focus at a point 40 inches from the glass.

The old way of enumerating the glasses was by the inch or a fraction thereof, as, for instance, a glass that would bring parallel rays to a focus at 40 inches was called $\frac{1}{40}$; one at 20 inches was called $\frac{1}{20}$; one at 10 was called $\frac{1}{10}$; etc. The new notation is by *meter* or *dioptres*. The following table shows the old enumeration in inches and their equivalents approximately in dioptres:

Inches.	Dioptres.	Inches.	Dioptres.
160	0.25	60	0.67
80	0.50	50	0.75

Inches.	Dioptres.	Inches.	Dioptres.
40	1.00	7	5.50
36	1.11	6½	6.00
30	1.25	6	6.50
24	1.50	5½	7.50
22	1.75	5	8.00
20	2.00	4½	9.00
18	2.25	4	10.00
16	2.50	3¾	10.50
14	2.75	3½	11.00
13	3.00	3¼	12.00
12	3.25	3	13.00
11	3.50	2¾	14.00
10	4.00	2½	16.00
9	4.50	2¼	18.00
8	5.00	2	20.00

APPENDIX.

PART I.

SYNOPSIS OF DATA GATHERED FROM THE EXAMINATION OF TWO THOUSAND AND FORTY SCHOOL-CHILDREN OF THE PUBLIC SCHOOLS OF KANSAS CITY, UNIVERSITIES OF KANSAS AND MISSOURI, STATE NORMAL AND OTHER DISTRICT SCHOOLS.*

Of 2040 pupils examined, there were:

1422	Americans.	67	Irish.
129	Germans.	47	English.
26	French.	11	Swedish.
15	Scotch.	93	mixed.

Of the 1422 Americans, 300, or 21.1 per cent, had some anomaly of refraction.

Of the 129 Germans, 32, or 24.8 per cent, were ametropic.

Of the	26 French,	5, or	19.2	per cent.	Were ametropic.
" "	15 Scotch,	3, or	20	" "	
" "	67 Irish,	20, or	29.87	" "	
" "	47 English,	8, or	17	" "	
" "	11 Swedish,	3, or	27.2	" "	
" "	93 mixed,	22, or	23.6	" "	

The Irish, Swedish, and Germans had the highest per cent of ametropia; the English, French, Scotch, and American the lowest. Out of the whole number examined (2040), 1162 were girls and 878 were boys. 458 had some ametropia. Of the

*Extract from a paper read before the Ninth International Medical Congres at Washington, D. C., 1887.

1162 girls, 290, or 24.9 per cent, were ametropic. Of the 878 boys, 168, or 19.1 per cent, were ametropic, there being a larger per cent of anomalies among the girls than the boys. In three grades of one school, the color of the eyes was not taken, but of those taken there were:

629½	pairs of blue,	99	hazel,
364	gray,	91	black.
443½	brown,		

Of the 629½ blue, 122, or 19.3 per cent, were ametropic.

Of	the	364	gray,	80½,	or	22.1	per cent.
"	"	443½	brown,	86½,	or	19.5	" "
"	"	99	hazel,	32,	or	32.3	" "
"	"	91	black,	18,	or	19.7	" "

Blue, brown, and black had the lowest per cent of affections, the hazel having to a marked degree the largest per cent of affections. Calling the blue and the gray the light-colored eyes, and the black, brown, and hazel the dark, the light have 20.3 per cent of affections and the dark 21.3 per cent of affections. In this calculation the eyes of the negroes were not considered. Out of the 2040 pupils—

13, or 0.6 per cent, had strabismus,
94, or 4.6 per cent, were myopic,
202, or 9.9 per cent, were hyperopic,
42, or 2.06 per cent, were astigmatic,
99, or 4.8 per cent, had spasm of accommodation, and
63, or 3.1 per cent, had latent hypermetropia.

We find that hypermetropia predominated; if we add latent hypermetropia and spasm of accommodation, saying nothing of astigmatism—of which

the majority were hyperopic—we have 364 hypermetropes to 94 myopes, or nearly four times as many hypermetropes as myopes, or over twice as many as all other anomalies taken together. All the grades from the primary through the grammar school, high school, normal school, and university were represented, but in no instance, except the Kansas State University, was there anything like a gradual increase of myopia or any of the anomalies, simply or collectively. In nearly all of the schools there seems to be a higher per cent of anomalies in the first years, then a little later in the course a marked diminution, and then again an increase. Probably many of those having some trouble, after remaining in school a short time, drop out, which would account for the diminution, and then spasm of accommodation and latent hypermetropia becoming manifest later on, or perhaps developing into myopia, would account for the increase in myopia.

School-life, however, so far as I can gather by these examinations, has comparatively little to do in the development of these anomalies. That they *exist*, however, in a *much greater* degree than is generally supposed is very evident, and that continuous use of the eyes (having these errors of refraction), whether in the school-room or out of it, if not corrected, is sure to have its evil consequences. The importance of a recognition of the existence of these anomalies, of their extreme frequency, and of detecting and correcting them, is obvious enough. We should take into consideration that spasm of accommodation and latent hyper-

metropia frequently exist, and that these affections often develop into myopia, and if recognized early and promptly treated by rest and glasses, much suffering and irremediable trouble is averted. Cohn and others may have been able, years ago, to trace the development of myopia to badly appointed school-rooms; but here in America our school-rooms are so carefully arranged as to light, seats, desks, ventilation, etc., that we can scarcely attribute to the work in the school-room the cause of anomalies. In a very great degree these errors of refraction are congenital; frequently they are latent, and if the eyes were not over-taxed (for near work), the ametropia would never become manifest. The evil arising from work in the school-room is that these errors of refraction are not perceived, and hence not corrected. If the teacher could be made to understand that the little pupil's complaining of headache, pain through the temples, and weakness of the eyes, or dimness of vision arose neither from stupidity nor desire to avoid study, but that these complaints were symptoms of some defect of the organ of vision; or, what would be better still, let a competent oculist carefully examine each child as he enters upon each year of study in the school-work, and his anomaly (if he has any) be corrected; errors of refraction would gradually diminish.

CONCLUSIONS.

1. I think that the principal information gained in these examinations is that 22.4 per cent of the school-children have some anomaly of refraction or accommodation, which should be recognized and corrected early.

2. That the hazel eyes, of all the colors, seem to be the ones most affected.

3. That the light eyes, upon the whole, are less liable to be ametropic than the dark.

4. That the females have a larger per cent of anomalies than the males.

5. That there is a much larger per cent of hypermetropia than of myopia.

6. That spasm of accommodation is a frequent anomaly.

Out of 458 of the full number of pupils having defective vision, the complete record of each eye of 408, taken separately, was kept, and of these, 326 had both eyes affected, although not equally so. Of the other 83 only one eye was affected. The relative vision of the right eye to the left, including all cases where but one only was affected as well as where both were, were found to be as 231:225; *i. e.*, Vision of R. E.·V. of L. E.:: 231:225.

From time to time, in the different medical journals, I have called attention to the great importance of having a careful examination made of school children's eyes by a competent oculist, that these different forms of ametropia may be recognized and timely treated, to prevent the serious consequences that are sure to follow in these ametropes ignorant of the necessity of wearing glasses and of further care and protection. It should be urged upon the part of every school board to assist in making a law requiring examinations by competent oculists.

In making these examinations, I am especially indebted to Professor J. M. Greenwood, Superintendent of our city schools, and to Prof. J. T. Buchanan, Principal of the Kansas City High School, for their hearty co-operation in obtaining these statistics.

PART II.

Fig. 181 represents a cabinet for holding various test types. It secures them from dust and warping and guarantees their presence when required.

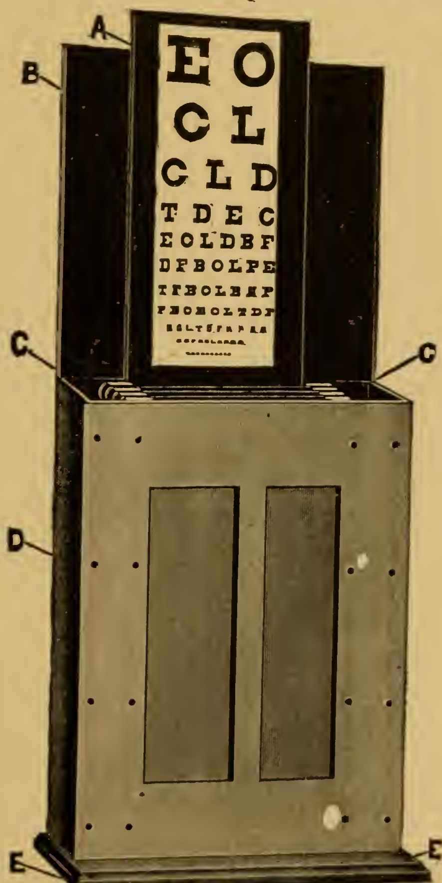


Fig. 181.

Figs. 183 and 184 represent a prism-measuring and lens-centering instrument.

In order to ascertain the degree of a prism, the latter is placed at the base of the instrument under the three prongs, and the indicator will point to the number at the upper part, indicating the strength of the prism in degrees.

In determining the center of a lens the latter is placed upon the lower points of the instrument, which are not, shown, as they are covered by the lens. The upper part of the instrument is then pressed down until the two outer points touch the lens, and when the indicator points to zero on the scale, the position of the central prong will indicate the center of the lens.

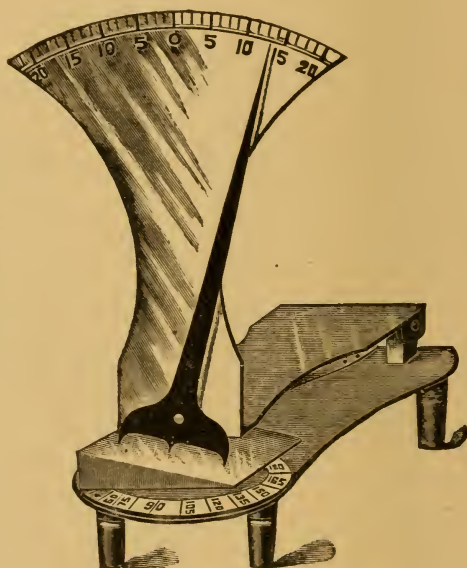


Fig. 183.

The lens measure (Figs. 185, 186, 187) has two stationary points (C, C) and one movable (B), which rests upon a lever (D) with cogs at its extremity, which play in the cogs of a wheel at the center (G), to which a pointer is attached. The lever is acted upon by the spring (H), which projects the central post slightly beyond the outer ones. The steel

spring (I) acts upon the indicator (K).

When the three posts are applied firmly to a perfectly plane surface, as a prism, the indicator will point to zero on the dial. If applied to a convex lens, it will go beyond the zero, and if the lens be 1 D.,

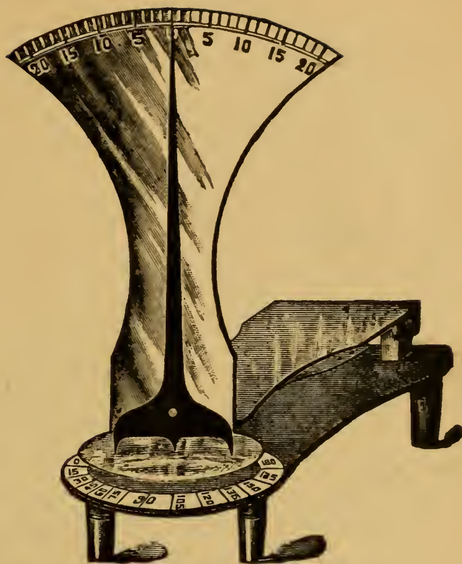


Fig. 184.

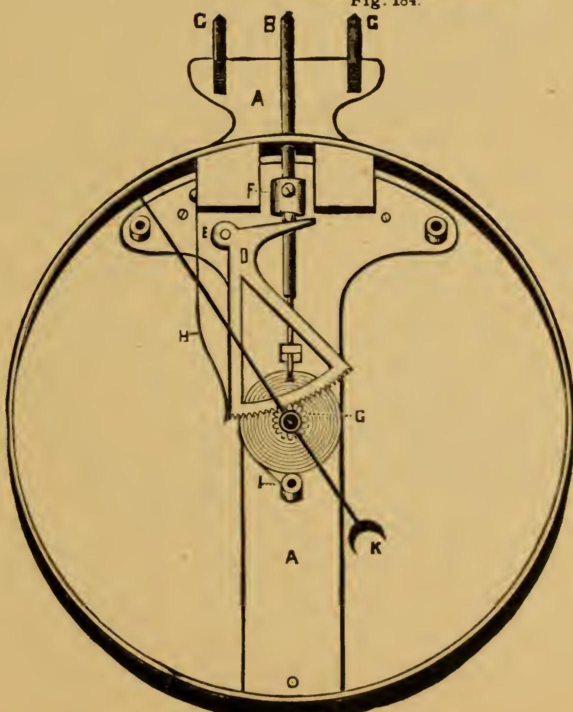


Fig. 185.

the indicator will point to +1. If applied to a concave lens, it will be moved towards the zero and will point to the number on the dial according to the degree of concavity.

Fig. 186

In case of plano-convex or concave only one side need be measured; namely, that of the convexity or concavity; but if it is bi-convex or bi-concave, both sides must be measured, and the sum of the two indicates the strength of the glass.

If it is a cylinder, the glass must be rotated when applied to the posts until the pointer comes to zero. The straight line running through the three posts is the axis of the cylinder. To ascertain the strength of the cylinder rotate the glass or the instrument at right angles to the former position, or until the highest number possible is reached. If it is concave, the pointer will be on the minus side; if convex, on the plus side of zero.

Fig. 187.

In concavo-convex (with the convexity preponderating), find the amount of the convex side; *e. g.*, 5 D.; then find the amount of the concave side, and if that be, for instance, — 3 D., then subtract the 3 from the 5, and we have a +2 D.

In convexo-concave lenses (with the concavity preponderating), subtract the amount of the convex side from that of the concave side, and the remainder gives the strength of the glass, which will be a minus

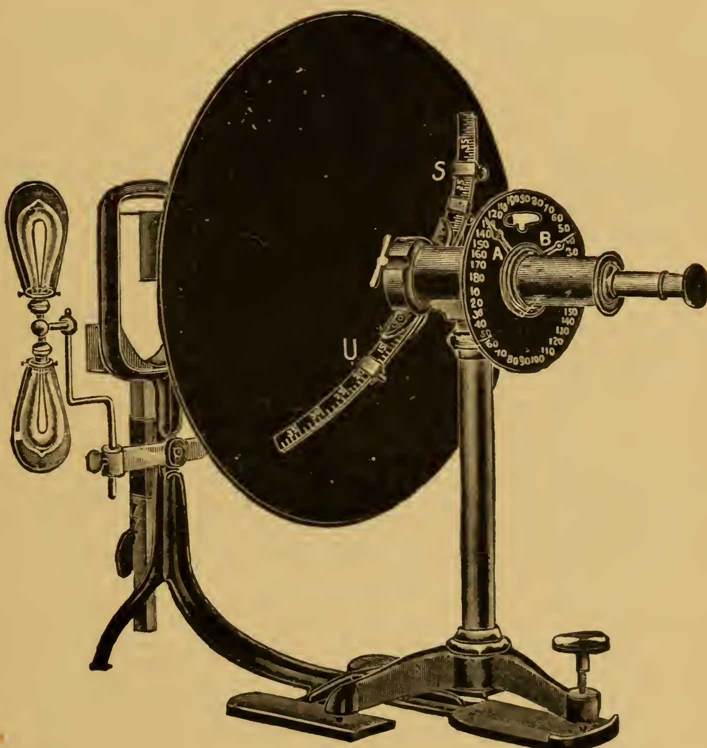


Fig. 188.

F. A. Hardy & Co.'s instrument. For description see page 191.

TEST TYPES.

No. 1. Diamond.

If men would enjoy the blessings of Republican Government, they must govern themselves by reason, by mutual counsel and consultation, by sense and feeling of general interest, and by the acquiescence of the minority in the will of the majority, properly expressed; and above all, the military must be kept, according to the language of our Bill of Rights, in strict subordination to the civil authority. The long processions of children and youths which we see to-day issuing by thousands from our free schools prove the care

No. 2. Pearl.

and anxiety with which a protective government provides for the education and morals of the people. Everywhere there is order, everywhere there is security, everywhere the law reaches to the highest and reaches to the lowest, to protect all their rights and to restrain all from wrong—and over all hovers Liberty. The English Colonists in America, generally speaking, were men who were seeking new homes in a new

No. 3. Nonpareil.

world. They brought with them their families and all that was most dear to them. They introduced the civilization of Europe into a wilderness without bringing with it the political institutions of Europe. The arts, science, and literature came with the settlers. The law of inheritance and descent came also, except that part of it which

No. 4. Minion.

recognizes the rights of primogeniture. The monarchy did not come, nor the aristocracy, nor the church as an estate of the realm. Political institutions were to be framed anew. A general social equality prevailed among the settlers, and an equality of political rights seemed the natural if not the neces-

No. 5. Brevier.

sary consequences. They brought with them a full portion of all the riches of the past, in science, in art, in morals, religion, and literature. The Bible came with them, and it is not to be doubted that to the free and universal reading of the Bible in that age men were much indebted for

No. 6. Long Primer.

right views of civil liberty. The Bible teaches man his own individual responsibility, and his own dignity, and his equality with his fellow-men. Bacon, Locke, Shakespeare, and Milton came with the colonists. Good English literature was read, spoken and

No. 7. Small Pica.

written before the axe had made way to let in the sun upon the habitations and fields of Plymouth and Massachusetts; and, whatever may be said to the contrary, a correct use of the English language is at this day more general throughout the

No. 8. Pica.

United States than it is throughout England herself. Another grand characteristic of the English colonies is that their political affairs were left to be managed

No. 9. 2-line Brevier.

by themselves. Home government, or the power of making in the colony the municipal laws which were to govern it,

No. 10. 2-line Long Primer.

equality of rights. Her obligations to Europe for science, art, laws, literature, and manners

No. 11. 2-line Pica.

America acknowledges as she ought with respect and gratification. Ameri-

No. 12. 3-line Pica.

ca has furnished
to Europe proof
of the fact, that

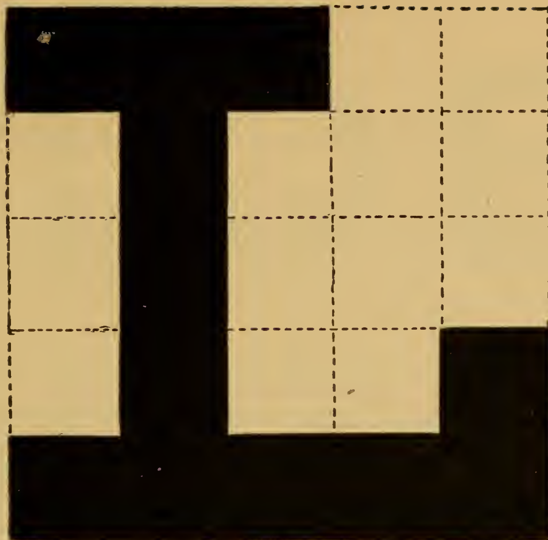
No. 13. 4-line Pica.

popular in-
stitutions,
founded on

No. 14. 5-line Pica.

equality
and the

D-CLX



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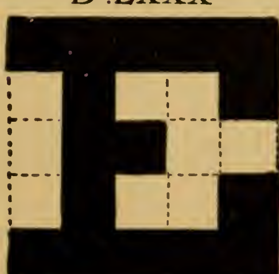

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Among the authors consulted in writing this book are: Fuchs, Landolt, Wells, Nettleship, Hartridge, Donders, Noyes, Juler, Meyer, Abadie, Williams, De Schweinitz, Helmholtz, Lawson, Swanzy; Schweigger, Schmidt- Rimpler, Volk, Roosa, Stevens, Savage, etc., and medical journals.